The Use of Caffeine to Enhance Cognitive Performance, Reaction Time, Vigilance, Rifle Marksmanship and Mood States in Sleep-Deprived Navy SEAL (BUD/S) Trainees

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14. Abstract Caffeine has been shown to improve tasks with a vigilance component. The purpose of this study was to determine the effectiveness of caffeine in sleep-deprived individuals exposed to high levels of operational and environmental stress. Volunteers were 68 Navy SEAL trainees. Volunteers were administered caffeine (100, 200, 300 mg or placebo) after 72 hrs of sleep deprivation. Performance testing occurred 1-1.5 hrs and 8-10 hrs after caffeine or placebo administration. Tests included auditory and visual vigilance tests, four-choice reaction time, matching to sample, repeated acquisition, rifle marksmanship, mood and subjective sleepiness assessment. The combined effects of sleep deprivation and the operational and environmental stress of training significantly affected all measures adversely (ANOVAs, $p<0.05$ to 0.0001). Caffeine (200 or 300 mg) significantly improved ($p<0.05$) visual vigilance, reaction time, repeated acquisition, mood and alertness measures compared to placebo when sleep-deprived. Marksmanship was not affected by caffeine.

15. Subject Terms Navy SEAL Training, Hell Week, BUD/S, Caffeine, Sleep Deprivation, Environmental Stress, Operational Stress, Vigilance, Cognitive Performance, Marksmanship, Reaction Time, Repeated Acquisition Test, Matching to Sample Test, Mood, Alertness, POMS, SSS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Caffeine has been shown to improve performance on tasks that have a vigilance component. The purpose of this study was to determine whether caffeine at various doses could improve mental performance in individuals who are sleep-deprived and exposed to high levels of environmental and operational stress in a combat-like training scenario. Sixty-eight Basic Underwater Demolition/SEAL (BUD/S) trainees from the Naval Special Warfare Center in Coronado, CA, volunteered and completed testing during BUD/S training. Testing occurred during the week of minimal sleep, intense physical, mental and environmental stress that is termed Hell Week. Volunteers were randomly assigned to one of four double-blind groups: three caffeine dose groups (100, 200, or 300 mg) or a placebo group. Performance and subjective assessments included auditory and visual vigilance tasks, four-choice reaction time, matching to sample and repeated acquisition cognitive tests, rifle marksmanship, the Profile of Mood States (POMS) and the Stanford Sleepiness Scale (SSS). Volunteers were trained on all these tests, and baseline performance levels were determined prior to Hell Week. A caffeine or placebo pill was given at 72 hours into Hell Week. Testing took place 1-1.5 hours and 8-10 hours after caffeine or placebo administration.

The effects of Hell Week and the associated sleep deprivation significantly affected all measures adversely ($p < 0.05$ to 0.00001). Beneficial dose-related effects of caffeine administration on a variety of behavioral parameters and mood states were observed ($p < 0.05$). Caffeine at 300 mg dose significantly improved visual vigilance and 200 mg had a nearly equivalent effect. The number of correct hits in the four-choice reaction time test was also significantly improved by 200 mg or 300 mg caffeine, as was time-to-completion in the repeated acquisition task. The POMS mood state of fatigue showed a significantly smaller increase after administration of 300 mg of caffeine compared to placebo. Those receiving the 200 mg or 300 mg caffeine doses showed significantly more SSS alertness with a dose response pattern evident. A greater proportion of subjects who received the 200 mg dose of caffeine felt that it helped their performance. Rifle marksmanship, the matching to sample task, and auditory vigilance tasks were not significantly improved by administration of caffeine, although changes were in a positive direction, with both 200 and 300 mg showing

smaller decrements in performance from baseline compared to placebo. Additionally, the use of caffeine did not negatively impact performance, produce muscle tremors, nor disrupt any of the subjective measures. Consumption of caffeine did not result in any increases in frequency of urination or fluid intake.

It is concluded that the use of either 200 or 300 mg of caffeine could help maintain performance during sleep deprivation, particularly on tasks with a visual vigilance component. Decision-making tasks requiring sustained attention such as the four-choice reaction time test (pressing the correct key) and the repeated acquisition test (learning a certain sequence of instructions) under sleep deprivation conditions are completed more rapidly and accurately when caffeine is taken. Furthermore, feelings of alertness are increased while feelings of fatigue are reduced when caffeine is administered in these doses under conditions where sleep deprivation is present. Hydration state and marksmanship, two areas of concern about the potential compromising effects of caffeine, were not negatively affected. Based on the results of this study, it is recommended that 200 mg of caffeine be used to improve mental performance caused by sleep deprivation during combat stress. This dose improved mental performance, had a beneficial subjective effect, and did not pose the physiological or psychological risks associated with higher doses.

INTRODUCTION

MILITARY RELEVANCE

Sustained work/sustained operations where lack of sleep is a critical issue has been a concern for some time (Angus and Heslegrave, 1985; Krueger and Engulund, 1985; Stretch and Jamieson, 1990). Combat doctrine for NATO countries emphasizes the need for 24-hour fighting capabilities (Stretch and Jamieson, 1990). The use of caffeine in appropriate doses and taken at the proper time in sleep-deprived individuals may be beneficial to war fighters that are involved in tasks where vigilance and precise, prompt action are required. Tasks such as sentry duty, radio communications, and flying of aircraft are all examples of specific relevant tri-service tasks this research addresses.

The ability of caffeine to sustain military tasks, such as rifle marksmanship during sentry duty or a sniping scenario, will meet the Special Forces' request (Special Operations, 1993) to improve military task performance. Many pharmacological agents have been tested in attempts to reduce decrements in soldier performance. Amphetamines have been shown to be effective, but have abuse and addiction potential and other possible negative side effects (Weiss and Laties, 1962). Caffeine has shown promise, but coffee and other such sources are not readily available during most special operations. This research, using Navy SEAL (Sea-Air-Land) trainees, examined the behavioral and physiological effects of supplemental caffeine. Of particular interest is the ability of caffeine to sustain vigilance in sleep-deprived individuals subjected to combat-like stress.

NAVY SEAL PROGRAM

The SEALs are specialized combat units within the U.S. Navy. They originated with a group of World War II volunteers selected from Naval Construction Battalions to clear the beaches for the amphibious group that invaded Sicily. It was at this time that the first formal training of the Naval Combat Demolition Units began. In 1962 the first

commissioned SEAL teams were established. Their mission was to conduct unconventional, counter-guerilla warfare and clandestine operations in maritime and riverine environments (Waller, 1994).

To become a Navy SEAL, an individual has to complete a four-part training program, the Basic Underwater Demolition/SEAL (BUD/S) program, which is taught at the Naval Special Warfare Center, Naval Amphibious Base, Coronado, CA. The rigorous mental and physical stress of this training accounts for the high 75% failure rate (Waller, 1994). The first part is a Pre-Training Phase where each student undergoes 4-7 weeks of physical training and indoctrination to the BUD/S community. The second part is called First Phase. This phase is the basic conditioning part of the program and lasts 9 weeks. Physical conditioning is emphasized during this phase and includes extensive running, swimming, calisthenics, and military obstacle course training. Other training during this period focuses on small boat seamanship, drownproofing, lifesaving, underwater knot tying, conducting hydrographic surveys, and sketching hydrographic charts. The sixth week of this phase is unofficially known as Hell Week. This week involves intense around-the-clock training with very little sleep. Substantial environmental and operational stress occurs during this week of training. It also has the highest dropout rate for any single week in BUD/S training. The Second Phase, the diving phase, is 7 weeks in duration. During this phase, students learn to use Self-Contained Underwater Breathing Apparatus (SCUBA). Emphasis is on long-distance diving and training students to become combat divers. The Third (and final) Phase lasts 9 weeks and provides training expertise in demolitions, reconnaissance, and land warfare. Skills practiced in this phase include land navigation, small-unit tactics, patrolling techniques, rapelling, parachuting, and individual weapons and explosives use.

BACKGROUND

Caffeine

Of the food constituents that may directly affect brain function and behavior, the most intensively studied has been caffeine. Caffeine is a member of a class of

substances termed the xanthines. Animal studies have provided strong evidence that caffeine's behavioral effects are mediated by the inhibitory neuromodulator, adenosine (Snyder, 1984). It appears that caffeine has the properties of a stimulant because it blocks the physiologic action of adenosine, an endogenous sedative-like compound. In-vitro studies have shown that low levels of caffeine compete with adenosine for occupancy of extracellular receptor sites. In addition, the rank order of potency of a number of caffeine-like substances for blocking adenosine A_1 receptors parallels their relative potencies in producing stimulant-like behavioral changes in animals (Snyder, 1984; Snyder, Katims, Annau et al., 1981). Unfortunately, little detailed information is available regarding the precise role of adenosine in regulating normal brain function.

Caffeine is considered by the general public to be a stimulant that increases alertness. However, many published reviews of the extensive scientific literature on caffeine fail to reach any definitive conclusion concerning the behavioral effects of this substance (Dews, 1982; Dews, 1984; Sawyer, Julia and Turin, 1982). In spite of numerous studies on caffeine given in relatively high doses, there is limited consensus among behavioral scientists regarding its effects. Many investigations of caffeine's behavioral effects have examined doses well above the amounts found in single servings of most beverages. Several recent studies have described improvements in certain types of performance among volunteers receiving various does of caffeine (Battig and Buzzi, 1986; Clubley, Bye, Henson et al., 1979; File, Bond and Lister, 1982; Lieberman, Wurtman, Emde et al., 1987; Lieberman, Wurtman, Garfield et al., 1987). However, other studies have not observed any positive effects of caffeine on vigilance, reaction time, or other types of performance (Franks, Hagendorn, Hensley et al., 1975; Goldstein, Kaizer and Warren, 1965; Loke and Meliska, 1984). As discussed below, a number of recent studies have demonstrated, in well-rested individuals, that caffeine in moderate doses improves the ability to maintain vigilance.

One variable frequently assessed in behavioral studies of caffeine is mood state. As might be expected, increased alertness has often been reported following caffeine administrations of 100 to 300 mg (Clubley, Bye, Henson et al., 1979; Goldstein, Kaizer and Warren, 1965; Lieberman, Wurtman, Garfield et al., 1987). In addition, a decrease in self-reported calmness occasionally has been observed at high doses (300 mg) (Cole, Pope, LaBrie et al., 1978). Other studies, however, have failed

to detect significant effects of caffeine on mood state (File, Bond and Lister, 1982; Svensson, Persson and Sjoberg, 1980). Mood assessment is a validated method to assess soldier effectiveness. When mood is significantly impaired, physical and mental performance also deteriorates (Conway and Giannopoulos, 1993; Dobson and Dobson, 1981; Morgan, 1984; Opstad, Ekanger, Nummestad et al., 1978).

A great deal of the variability in results regarding caffeine's effects on human behavior can be accounted for by methodological differences, misinterpretation of apparently negative results, and the failure of many investigators to take into account important confounding factors such as prior history of caffeine use (for a review, see Lieberman, 1992). Another area often overlooked is the extent of tobacco use, even though smoking substantially decreases the plasma half-life of caffeine.

Selection of appropriate behavioral tasks is particularly critical in order to consistently document the effects of caffeine. The literature on caffeine's effects on performance provides numerous examples of the critical nature of test selection. In well-rested individuals it has been shown that caffeine affects learning on complex cognitive tasks (Sawyer, Julia and Turin, 1982). However, many investigators report positive effects of moderate doses of caffeine on tests with substantial vigilance components (Clubley, Bye, Henson et al., 1979; Lieberman, Wurtman, Emde et al., 1987; Lieberman, Wurtman, Garfield et al., 1987; Regina, Smith, Keiper et al., 1974), although others failed to detect effects of even higher doses of caffeine on such tasks (Loke and Meliska, 1984).

Caffeine and Vigilance

Several characteristics of vigilance tests that increase the probability of detecting effects of caffeine are duration of task and the rate of stimulus administration. The Continuous Performance Task (CPT), an adaptive test of visual vigilance, is a relatively short duration test and appears to be less sensitive to the effects of low and moderate doses of caffeine than the much longer Wilkinson Auditory Vigilance Test (Clubley, Bye, Henson et al., 1979; Lieberman, Wurtman, Emde et al., 1987; Lieberman, Wurtman, Garfield et al., 1987). Long duration tests of simulated driving that have a substantial visual vigilance component also have

detected effects of caffeine at moderate and high doses (Baker and Theologus, 1972; Regina, Smith, Keiper et al., 1974). However, duration does not appear to be the only critical parameter which distinguishes vigilance tests that detect effects of caffeine from those that do not. Rate of stimulus administration is another parameter that increases the probability of detecting effects of caffeine. A study conducted by Loke and Meliska (1984) failed to observe any effects of moderate and high doses (195 or 325 mg) of caffeine, even though the vigilance task was 90 minutes in duration. However, in this task, a relatively large number of signal trials (22%) were presented, as compared to only 2% in the Wilkinson vigilance task. Responding to a stimulus frequently is less monotonous than continuous monitoring without a response stimulus. Monotony of the task is a critical characteristic of vigilance tasks, as it produces boredom and fatigue compromising performance (Holland, 1968). Task monotony was minimal in the above task, which probably accounted for the failure to detect caffeine effects. Because subjects detected about 90% of the test stimuli as compared to a typical hit rate of 50% on the Wilkinson vigilance task, this demonstrates that the task was too easy to begin with, and that the stimulating effects of caffeine were not necessary to improve performance to a high level. In a series of three studies (Lieberman, 1989; Lieberman, Wurtman, Emde et al., 1987; Lieberman, Wurtman, Garfield et al., 1987), all of which used a modified version of the Wilkinson Vigilance Test, caffeine consistently improved performance when administered in doses between 32 and 256 mg in the morning. In all, more than 75 subjects participated in this series of double-blind, placebo-controlled crossover studies. These studies provide the most consistent documentation of a behavioral effect of caffeine in a range of doses equivalent to those present in foods.

Since visual information is often critical for a number of military tasks, a validated visual, as opposed to an auditory vigilance task, was developed at USARIEM (Fine, Kobrick, Lieberman et al., 1994). The new visual task is similar in certain key aspects to the Wilkinson Vigilance Test, such as rate of stimulus administration. When this task was used in a recent USARIEM study, performance was improved after consuming 200 mg of caffeine compared to the placebo condition (Fine, Kobrick, Lieberman et al., 1994).

In another USARIEM study which used simulated rifle marksmanship to assess

performance, Johnson (1991) showed that 200 mg of caffeine improved speed of target detection while accuracy was maintained. A follow-up study produced the same results for both men and women (Johnson and Merullo, 1996). In these studies, an M16 rifle weapon simulator, the Weaponeer, was used in a sentry duty scenario.

An ambulatory, wrist-worn auditory vigilance monitor designed and constructed at USARIEM was also used to study vigilance in the current study. The device was designed to duplicate the critical characteristics of the vigilance tasks used in previous studies with caffeine and other treatments (Fine, Kobrick, Lieberman et al., 1994; Lieberman, Mays, Shukitt-Hale et al., 1996; Lieberman, Wurtman, Emde et al., 1987; Lieberman, Wurtman, Garfield et al., 1987). This device permitted continuous assessment of vigilance while volunteers went about their standard training routine.

OBJECTIVES

The purpose of this study was to investigate the use of caffeine in sleep deprived Navy BUD/S trainees to enhance vigilance and maintain cognitive and marksmanship performance. Three doses (100, 200, and 300 mg) were given to determine the optimal dose that would enhance or maintain performance in sleep-deprived, operationally stressed BUD/S trainees. Testing was done during Hell Week of the First Phase of BUD/S training. Beneficial effects and possible adverse side effects of caffeine use were determined and documented. No other study using the operational stresses such as those imposed during Hell Week has ever been conducted to assess the potential benefits of caffeine in scenarios where sleep deprivation is severe, yet the requirement for performance on cognitive tasks remains high. The stress of Hell Week is as close to real combat stress as is imposed in military training. Hence, it made for an ideal testing environment to evaluate the effects of caffeine during combat-like stress.

Hypotheses Tested

1) To determine whether caffeine in various doses improves vigilance when administered to stressed, sleep-deprived BUD/S trainees.

2) To determine whether caffeine alters cognitive performance, reaction time, marksmanship, and alertness; and whether it relieves the psychological fatigue associated with sleep deprivation in BUD/S trainees.

3) To determine whether caffeine affects mood and hydration state.

4) To examine interactions between baseline caffeine consumption patterns, tobacco use, and caffeine administration.

5) To determine the effects of sleep deprivation on cognitive performance, reaction time, vigilance, marksmanship, mood, and alertness.

METHODS

GENERAL PROCEDURE

This was a double-blind, between-subjects placebo controlled study. The study was conducted at the Naval Special Warfare Training Center in Coronado, CA. Background demographic information (a copy of the questionnaire may be found in the Appendix), training on the individual test procedures, and baseline pre-caffeine data collection were assessed prior to Hell Week. Hell Week began on a Sunday night. The following Wednesday night at approximately 2100, the administration of caffeine/placebo occurred. The volunteers had only slept for 1.5 hours since Sunday night, and this sleep occurred approximately 15 hours prior to receiving caffeine and testing. A total of approximately 72 hours without sleep (except for the 1.5 hours just mentioned) occurred during this time period. BUD/S trainees are not permitted to consume coffee, to smoke, or to have any personal food during Hell Week. Only non-caffeinated beverages were allowed while in the mess hall. It is possible that a small amount of food containing caffeine could have been consumed, but these foods are banned during normal BUD/S training and an individual would be risking his standing in class by consuming such items. No information was obtained on any individuals

consuming caffeinated foods during Hell Week.

There were four dosing groups with random assignment to one of three caffeine treatments (100, 200, or 300 mg) or placebo. Administration of caffeine doses and placebos were in pill form; the number of pills taken and the physical characteristics of the pills were identical between groups to ensure double-blind administration.

Volunteers underwent their regular training exercise for about an hour after caffeine/placebo ingestion, which occurred on the training beach at the Naval Special Warfare Training Center. Following this training, at approximately 1 hour after caffeine/placebo ingestion, volunteers came to the field-testing laboratory. Volunteers were randomly divided into two testing groups, and each group was assigned to an adjacent room for testing. Different dosing groups were represented in each testing group. Tests were grouped based upon time to complete the test and upon availability of lap-top computers. Description of the tests can be found below. Group 1 began by having saliva samples obtained, then filled out the POMS and SSS questionnaires, completed the USARIEM Visual Vigilance task, had rifle marksmanship assessed and received their vigilance monitors. Group 2 began with the three other computerized tests (Four-Choice Visual Reaction Time, Matching to Sample, and Repeated Acquisition). After completing the first set of tests, the groups exchanged rooms and performed the second set of tests (i.e., Group 1 did the computerized tasks, while Group 2 did marksmanship and other associated tasks). Volunteers moved to the next station after completion of their tasks. After all stations were completed (which took approximately 1 hour), volunteers donned their vigilance monitors and proceeded with their regularly scheduled BUD/S training. This training was physically demanding and included such tasks as running, lifting, swimming, calisthenics, and paddling of life rafts. Training was the same for all volunteers. At 8-10 hours after caffeine/placebo ingestion, volunteers turned in their vigilance monitors and repeated the testing described above. In addition, at this time they filled out the two-item hydration state questionnaire and a post-test questionnaire.

SALIVA SAMPLE PROCEDURE

Saliva samples were collected to obtain measures of background caffeine in the system and to assess changes in caffeine levels following administration of caffeine. Volunteers provided 10 ml samples of saliva on four different occasions by chewing on cotton to absorb saliva, which was deposited into a special centrifuge tube (Sarstedt; Newton, NC) for chemical analysis. Samples were taken 1) once prior to Hell Week, 2) immediately prior to caffeine/placebo ingestion, 3) 1-1.5 hours after caffeine/placebo ingestion (time of peak level of caffeine in plasma), and 4) 8-10 hours after caffeine/placebo ingestion (the approximate duration of the half-life of caffeine in plasma) (Von Borstel, 1983).

VIGILANCE, REACTION TIME AND COGNITIVE TESTING PROCEDURES

Four computer tests were administered on laptop computers: visual vigilance, four-choice reaction time, matching to sample, and repeated acquisition. Each test was administered in a baseline session, and 1-1.5 hours after, and again, 8-10 hours after caffeine/placebo ingestion. Volunteers had received practice on these tests before actual testing.

USARIEM Visual Vigilance Test

This test followed procedures used previously (Fine, Kobrick, Lieberman et al., 1994) which required the volunteer to detect a faint dot that appeared randomly on the screen for 2 seconds. Average presentation of the dot occurred once a minute. Upon detection of the dot the volunteer pressed the space bar on the keyboard as quickly as possible. The computer recorded whether or not a stimulus was detected and the response time for the detections. Responses made before or after stimulus occurrence were recorded as false positives. Each session lasted 15 minutes.

Four-Choice Visual Reaction Time Test

Reaction time tasks are susceptible to the stress imposed by the lack of sleep

(Bonnet 1985, 1987, 1989) and by the external environment (Banderet and Lieberman, 1989). Tests of visual reaction time administered using portable laptop computers followed procedures used previously (Banderet and Lieberman, 1989; Dinges, 1992). Volunteers were presented with a series of visual stimuli at one of four different spatial locations on the computer screen. They had to indicate the correct spatial location of each stimulus by pressing one of four adjacent keys on the computer keyboard. The measurements recorded included correct responses and incorrect responses (hitting the wrong key), the response latency for each trial, premature errors (responding before the presentation of the stimulus), and time-out errors (response latency greater than one second). Two hundred and fifty trials were administered.

Matching to Sample Test

This test assesses short-term spatial memory (working memory) and pattern recognition skills. The volunteer responded by pressing the down arrow key when the word "READY" appeared on the screen. The volunteer was then presented with an 8 X 8 matrix of a red and green checkerboard on a color screen. The matrix was on the screen for 4 seconds. The sample was removed and followed by a variable delay interval during which the screen was blank (except for the word "delay" at the bottom of the screen). The delay was either 1 or 15 seconds. After the delay, two matrices were presented on the screen: the original sample matrix, and another matrix that differed slightly in that the color sequence of two of the squares was reversed. The volunteer selected the comparison matrix by responding on the left or right arrow key that matched the original sample matrix. The task consisted of 20 trials, 10 at each delay. A comparison response (left or right arrow key) had to be made within 15 seconds, otherwise a time-out error was recorded. Correct responses were also recorded, as was response time to choose the matrix.

Repeated Acquisition Test

This test assesses the ability to learn and acquire information. The volunteer had to learn a sequence of 12 key presses on the four arrow keys. The outline of a rectangle was presented on the screen at the beginning of a trial. Each correct response filled in a portion (1/12th) of the rectangle from left to right with a solid yellow

color. Each incorrect response blanked the screen for 0.5 seconds. When the screen returned, the volunteer was at the same point in the sequence as before the incorrect response. The volunteer had to learn the correct sequence by trial and error. When a sequence was correctly completed, the rectangle became filled, the screen then blanked, and another empty rectangle reappeared for the next trial. A session ended when the volunteer completed 15 correct sequences (15 trials). Each session consisted of a sequence randomly selected from a list of 32 different sequences. Each time a new session was started, a new sequence was selected for that session. Incorrect responses and time to complete each trial were recorded.

PROFILE OF MOOD STATES (POMS) QUESTIONNAIRE PROCEDURE

The POMS is a paper and pencil inventory of subjective mood states (McNair, Lorr and Droppleman, 1971). The volunteers rated a series of 65 mood-related adjectives on a five-point scale, in response to the question, "How are you feeling right now?". Previous research (McNair, Lorr and Droppleman, 1971) has shown that the adjectives factor into six mood sub-scales (tension, depression, anger, vigor, fatigue, and confusion). Total mood disturbance was determined by adding the five negative sub-scales minus vigor, and adding 100 to the score to eliminate negative values as has been done previously (Morgan, O'Connor, Sparling et al., 1987; O'Connor, Morgan and Raglin, 1991). Four of the sub-scales (tension, depression, vigor, and fatigue) have been shown to be sensitive to caffeine administration (Fine, Kobrick, Lieberman et al., 1994; Lieberman, Wurtman, Emde et al., 1987; Lieberman, Wurtman, Garfield et al., 1987). The POMS was administered pre-Hell Week (baseline), 1-1.5 hours after caffeine/placebo ingestion and again 8-10 hours after caffeine/placebo ingestion. A copy of this questionnaire may be found in the Appendix.

STANFORD SLEEPINESS SCALE (SSS) PROCEDURE

The SSS is a paper and pencil scale of seven descriptive statements of a person's state of sleepiness (Hoddes, Zarcone, Smythe et al., 1973). The volunteers

circled the one statement that most closely described their state of sleepiness. The SSS was given at the same times as the POMS. A copy of this questionnaire may be found in the Appendix.

MARKSMANSHIP PROCEDURE

Rifle marksmanship was quantified with a laser marksmanship simulator (Noptel ST-1000, Oulu, Finland) attached to a disabled AK-47 rifle. This simulator system has been used to assess marksmanship performance in a number of different research settings at USARIEM and has been proven to be a reliable and valid method of assessing marksmanship in the lab or in the field. Strategies to improve or quantify marksmanship performance under a variety of stressors have been previously reported (Tharion, 1996). Marksmanship parameters assessed were the distance from center of mass (DCM), shot group tightness (SGT), horizontal shot group tightness (HSGT), vertical shot group tightness (VSGT), number of missed targets (MISS), and sighting time (STIME). These measures have been described in detail previously (Tharion, Hoyt, Marlowe et al., 1992). The simulator consists of a laser transmitter, an optical glass laser-sensitive receiver with an associated paper aiming target, a personal computer, a printer, manufacturer supplied software, and a disabled AK-47 rifle. The laser transmitter emits a continuous 0.55 mm, 0.8 μm wavelength beam, which is invisible to the eye, that allows aiming positions to be monitored and recorded throughout the sighting and shooting process. A vibration sensor in the laser detects when the weapon is dry-fired. Shot location of the laser is recorded via its position on the optical glass laser sensor. The target that was used was a 2.3-cm diameter circular target located 5 meters away. This simulates a 46-cm diameter target at 50 m, which is similar to the standard 49 cm wide "100 m military silhouette man" used on training and qualifying ranges for the U.S. Army.

Volunteers were tested for marksmanship speed and accuracy. During assessment, volunteers lay prone using sandbags for support with the rifle in the shooting position 5 meters from the target. Following a "ready signal" and a 1-10 second (randomly varied) preparatory interval, a red LED light positioned 16 cm to the lower left of the target was illuminated as the signal to shoot. The volunteer then fired

at the target as quickly as possible while trying to maintain accuracy. A total of 8 shots or "trials" (a trial consisting of waiting for the light, sighting the target and pulling the trigger vs. firing multiple shots upon illumination of the red stimulus light) were taken per assessment. Marksmanship measures were assessed in two groups of four shots each and then averaged for each marksmanship assessment period. Marksmanship was assessed prior to Hell Week, 1-1.5 hours and 8-10 hours after caffeine/placebo administration.

AUDITORY VIGILANCE MONITOR PROCEDURE

The vigilance monitors are lightweight devices that were worn on the non-dominant wrist. Each monitor contains a 16-bit microprocessor, 128k of memory, a solid state accelerometer and various other components. These devices are somewhat larger than a large wrist-watch. At random intervals, averaging approximately 20 times an hour, they emitted an audible tone sequence. Monitors had a variety of distinct tone sequences. All tone sequences were equally salient. The volunteer was required to push a small button as quickly as possible on the monitor in response to the tone. Measures of vigilance and response time were assessed through this device by obtaining the number of correct responses and the latency to respond to the tone. Volunteers wore the monitors for approximately 8 hours after caffeine/placebo administration. The volunteers became familiar with the use of these monitors during the baseline period.

HYDRATION STATE QUESTIONNAIRE PROCEDURE

Volunteers were asked during the second test session (8-10 hours post-caffeine/placebo ingestion) to fill out a two-item questionnaire. The questions were:

1. How many times did you urinate since receiving your pill?
2. What and how much did you drink since receiving your pill?

This brief questionnaire roughly assessed fluid exchange and possible effects of diuresis that may have occurred as a result of caffeine ingestion.

POST-TEST QUESTIONNAIRE PROCEDURE

A post-test questionnaire was administered to obtain information on whether the volunteers believed they had caffeine or not. They were also asked if they believed it helped or hurt their performance and whether they felt any negative side effects. A copy of this questionnaire may be found in the Appendix.

STATISTICAL ANALYSES

Descriptive statistics were obtained to establish measures of central tendency and level of dispersion by caffeine dose at baseline, and 1-1.5 hours and 8-10 hours after dosing with caffeine or placebo. A repeated measures (time) analysis of variance (ANOVA) with a grouping factor (caffeine dose) was conducted on each dependent variable of the various performance tests: computerized performance tests, auditory vigilance, rifle marksmanship, mood states via the POMS, level of alertness via SSS, and caffeine concentrations using the saliva assays. One-way ANOVAs with change from baseline by caffeine for the 1-1.5 hour measure and the 8-10 hour measures by dose were also run because of differences in baseline measures between individuals. Post-hoc differences were evaluated using Duncan's multiple comparison tests, based on $p \leq 0.05$ and $p \leq 0.01$ levels of statistical significance. Frequency cross-tab tables for subjective effects of caffeine were obtained by caffeine group with a chi-square analysis run to obtain differences in observed frequencies between caffeine groups.

RESULTS

DEMOGRAPHIC INFORMATION

The entire BUD/S class (n = 89) volunteered for this study. All of these volunteers were trained on the procedures used in this study. However, only those individuals that had made it through to Wednesday night of Hell Week were included for testing in this study (this was the time of dosing; Hell Week began at approximately 2100 hours Sunday night). A total of 68 BUD/S trainees took part in this testing. Differences in the number of volunteers shown in the tables of this report represent missing data. Tables 1 and 2 summarize various demographic characteristics. No significant differences in any of the demographic characteristics existed between caffeine groups.

Table 1. Means and Standard Deviations of Demographic Characteristics of 64 BUD/S Volunteers.

DEMOGRAPHIC CHARACTERISTIC	MEAN ± S.D.
Age (yrs.)	23.9 ± 3.0
Height (inches)	69.8 ± 2.9
Weight (pounds)	170.1 ± 17.5
Time in Military (months)	34.5 ± 37.4
Sleep/Night (avg. number of hours)	6.9 ± 1.8

Table 2. Frequencies and Percent Breakdown of Race, Rank and Prior Marksmanship Experience of BUD/S Volunteers Completing the Study.

DEMOGRAPHIC CHARACTERISTIC	FREQUENCY	%
Race		
Caucasian (White)	52	91
Asian	2	4
Hispanic	2	4
Mixed/Other	1	2
African American (Black)	0	0
Rank		
E1-E3	25	48
E4-E6	13	25
O1-O4	14	27
Shoot Recreationally	41	72
Last Basic Rifle Qualification		
Never Tested	45	79
Unqualified	0	0
Marksman	4	7
Sharpshooter	2	3
Expert	6	11

EFFECTS OF CAFFEINE

Levels of caffeine were obtained using salivary assays. These values may be found in Table 3. It can be seen at 1 hour post-ingestion that significant differences existed between all four dosing groups ($p < 0.05$), with caffeine levels increasing as

Table 3. Salivary Levels of Caffeine During Baseline Testing, Pre-Drug Ingestion, 1-1.5 Hours Post, and 8-10 Hours Post-Drug Ingestion.

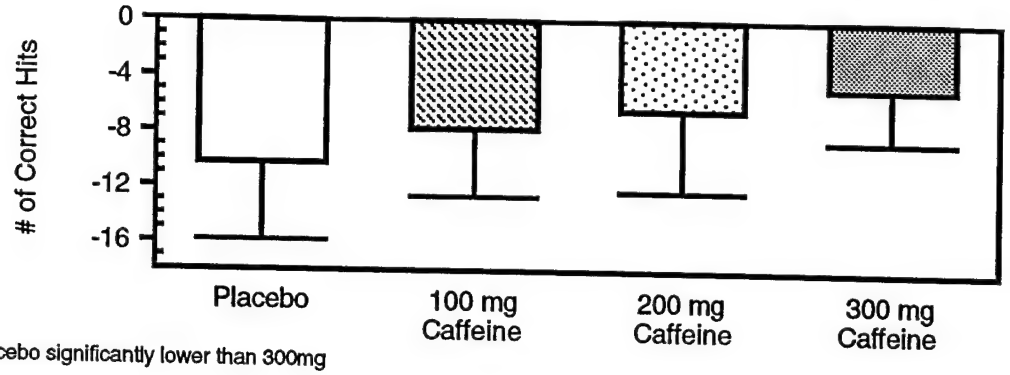
Salivary Caffeine Levels	**Placebo MEAN ± S.D. (*n*=14)**	**100 mg Caffeine MEAN ± S.D. (*n*=16)**	**200 mg Caffeine MEAN ± S.D. (*n*=13)**	**300 mg Caffeine MEAN ± S.D. (*n*=15)**	**Significance**
Baseline *(ug/mL)*	0.51 ± 0.56	0.60 ± 0.63	0.66 ± 0.69	0.59 ± 0.54	NS
Pre-caffeine (ug/mL)	0.46 ± 0.30	0.54 ± 0.32	0.62 ± 0.49	0.59 ± 0.43	NS
1-1.5 hours post *(ug/mL)*	0.43 ± 0.26	1.59 ± 0.40	2.94 ± 0.63	4.31 ± 0.65	0.001
8-10 hours post *(ug/mL)*	0.51 ± 0.26	1.03 ± 0.51	1.32 ± 0.46	2.40 ± 0.87	0.001

higher doses were administered. By 8-10 hours post-pill ingestion, differences still existed between groups, except between the 100 and 200 mg groups. No differences between baseline measured 4 days prior to Hell Week and pre-caffeine levels measured during Hell Week were observed. This suggests that typical dietary levels of caffeine on average were not high, hence withdrawal of caffeine during Hell Week did not occur. The interactive effects of smoking with caffeine administration would also be minimal, as smoking or tobacco use during Hell Week was not permitted. Withdrawal from tobacco products also should not have had a major impact because no volunteers smoked and only 18% chewed tobacco. Background information on consumption of foods containing caffeine and tobacco use may be found in Tables A1-A5 of the Appendix. The use of medications during BUD/S training or taken regularly was minimal. This information is summarized in Table A6 in the Appendix.

Visual Vigilance

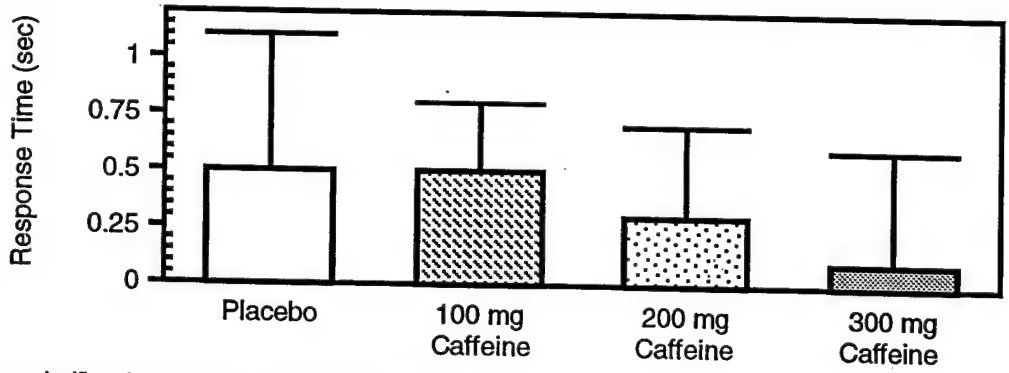
A significant change ($p < 0.05$) from baseline was observed for number of correct hits (Figure 1) and response time (Figure 2) for visual vigilance at 1-1.5 hours post-administration (i.e., when caffeine would be most active). As drug dosage increased, more targets were detected and the response time was shorter. The number of correct hits detected by the 300 mg group had a significantly smaller ($p < 0.05$) decrement compared to the placebo group. Response time for the 300 mg group increased significantly less ($p < 0.05$) than either the placebo or 100 mg groups. The 200 mg group did not differ from any other group. At 8-10 hours post-administration, a significant effect in change from baseline for the number of correct hits still existed ($p < 0.05$) with the 300 mg group having a significantly smaller decrement ($p < 0.05$) from baseline than either the placebo or 100 mg group (Figure 3). The greatest number of false positive hits were in the placebo condition, which coincides with the poorer performance of less actual targets detected and a slower response time to those targets. However, the least number of total false positive hits was in the 100 mg group. Means and standard deviations by caffeine group for the various visual vigilance measures are shown in Table 4.

Figure 1. USARIEM Visual Vigilance Test (# of Correct Hits) Score Change from Baseline by Caffeine Level at 1-1.5 Hours Post-Caffeine Administration.



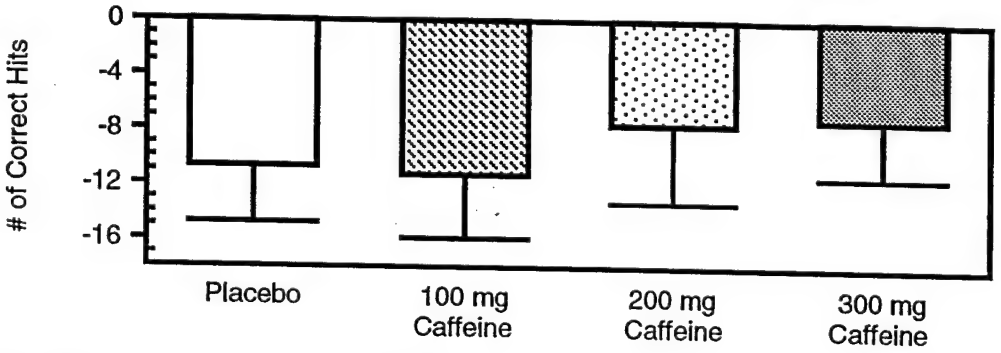
* Placebo significantly lower than 300mg

Figure 2. USARIEM Visual Vigilance Test (Response Time in Seconds) Score Change from Baseline by Caffeine Level at 1-1.5 Hours Post-Caffeine Administration.



* 300mg significantly lower than 100mg and placebo

Figure 3. USARIEM Visual Vigilance Test (# of Correct Hits) Score Change from Baseline by Caffeine Level at 8-10 Hours Post-Caffeine Administration.



* 300mg significantly lower than placebo and 100mg

Table 4. Visual Vigilance Score Measures by Level of Caffeine at 1-1.5 Hours Post-Administration in 58 BUD/S Trainees.

	PLACEBO MEAN ± S.D. (*n*=15)	100 mg CAF MEAN ± S.D. (*n*=16)	200 mg CAF MEAN ± S.D. (*n*=14)	300 mg CAF MEAN ± S.D. (*n*=13)
Hits: Total = 20	7.9 ± 5.4	10.6 ± 5.7	11.9 ± 5.9	12.2 ± 4.9
Total False Positive Hits	65.7 ± 143.1	28.6 ± 55.4	55.2 ± 176.5	48.2 ± 124.7
Response Time (sec)	1.4 ± 0.6	1.3 ± 0.4	1.2 ± 0.4	1.0 ± 0.4

Table 5. Four-Choice Reaction Time Score Measures by Level of Caffeine at 1-1.5 Hours Post-Administration in 59 BUD/S Trainees.

	PLACEBO MEAN ± S.D. (*n*=14)	100 mg CAF MEAN ± S.D. (*n*=15)	200 mg CAF MEAN ± S.D. (*n*=15)	300 mg CAF MEAN ± S.D. (*n*=15)
Correct Hits: Total = 250	201.2 ± 57.1	220.3 ± 37.2	231.7 ± 20.6	235.0 ± 14.6
Latency: Cor. Hit (ms)	626.0 ± 83.6	669.6 ± 117.2	624.4 ± 109.2	644.2 ± 122.8
Latency: Inc. Hit (ms)	467.2 ± 258.3	494.5 ± 246.8	494.5 ± 158.0	521.0 ± 190.0
Premature Errors (Tot.)	5.0 ± 11.7	2.3 ± 2.9	0.3 ± 0.5	0.6 ± 1.1
Time-out Errors (Tot.)	15.2 ± 15.0	15.8 ± 22.6	5.3 ± 11.7	6.5 ± 11.6

Four-Choice Visual Reaction Time

A significant difference ($p < 0.05$) was observed in change from baseline between drug groups for total correct hits (Figure 4), with the 300 and 200 mg groups showing a smaller drop in correct hits ($p < 0.05$) than did the placebo group. Latency of the response for correct or incorrect hits showed no statistical nor practical differences. An average 10-fold difference in premature errors occurred between the placebo group (mean = 5.0 errors) vs. the 200 and 300 mg groups (mean = 0.4 errors). Similarly, over twice the number of time-out errors were committed on average in the placebo and 100 mg groups as compared to the 200 and 300 mg groups. All of these measures showed great variability between subjects, negating significant findings at ($p < 0.05$) level of significance. No significant differences were seen between drug groups at 8-10 hours post-administration. A complete summary of all reaction time measures may be found in Table 5.

Matching to Sample

Means and standard deviations by caffeine groups for the various matching to sample measures are presented in Table 6. Using the change from baseline measure, no significant differences were seen between the drug groups at 1-1.5 hours post-administration for this test when considering all the trials (those with both short and long delays). The 300 mg dose exhibited the highest level of performance, showing the least impairment from baseline, although these differences were not significant. Additionally, this group had the highest number of correct responses, the shortest reaction time, and the least amount of time-out errors (Table 6). The placebo group had the poorest performance on all measures. Correct responses increased and time-out errors decreased when increasing drug dose. A separate analysis using only trials with the long delay (15 seconds) showed similar results, with no significant difference between the drug groups on any of the dependent measures. Change from baseline data for the 8-10 hour post-administration session also did not show any significant differences between the drug groups; all groups showed similar performance.

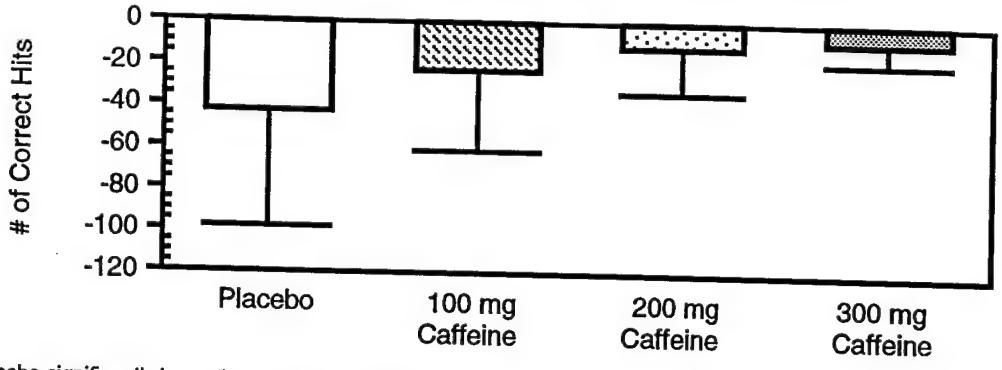
Table 6. Matching to Sample Score Measures by Level of Caffeine at 1-1.5 Hours Post-Administration in 67 BUD/S Trainees.

	PLACEBO MEAN ± S.D. (*n*=17)	100 mg CAF MEAN ± S.D. (*n*=17)	200 mg CAF MEAN ± S.D. (*n*=17)	300 mg CAF MEAN ± S.D. (*n*=16)
Correct Responses (Tot.)	9.2 ± 3.4	10.5 ± 3.1	10.8 ± 3.7	12.1 ± 2.9
Response Time (Sec.)	6.7 ± 3.0	6.3 ± 2.3	6.7 ± 2.3	5.6 ± 1.4
Time-out Errors (Tot.)	3.4 ± 5.0	2.4 ± 3.4	2.0 ± 3.2	0.5 ± 1.0

Table 7. Repeated Acquisition Score Measures by Level of Caffeine at 1-1.5 Hours Post-Administration in 66 BUD/S Trainees.

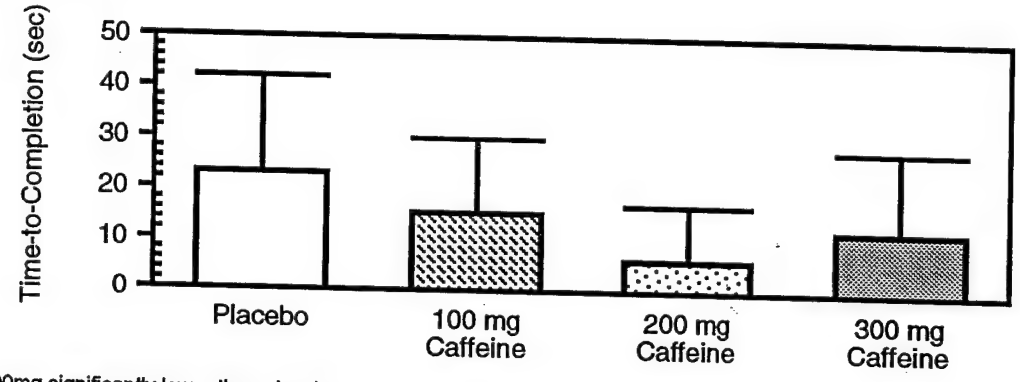
	PLACEBO MEAN ± S.D. (*n*=17)	100 mg CAF MEAN ± S.D. (*n*=16)	200 mg CAF MEAN ± S.D. (*n*=17)	300 mg CAF MEAN ± S.D. (*n*=16)
Incorrect Responses	13.3 ± 5.8	12.5 ± 4.0	10.4 ± 5.9	10.4 ± 5.8
Time-to-Completion (sec)	43.3 ± 19.4	38.0 ± 16.4	28.6 ± 11.7	34.5 ± 19.0

Figure 4. Four-Choice Reaction Time Test (# of Correct Hits) Score Change from Baseline by Caffeine Level at 1-1.5 Hours Post-Caffeine Administration.



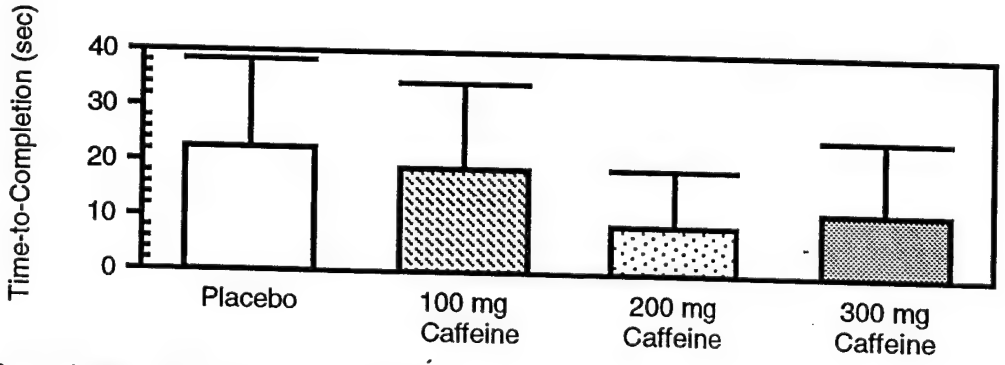
* Placebo significantly lower than 200mg or 300mg

Figure 5. Repeated Acquisition Test (Time-to-Completion in Seconds) Score Change from Baseline by Caffeine Level at 1-1.5 Hours Post-Caffeine Administration.



* 200mg significantly lower than placebo

Figure 6. Repeated Acquisition Test (Time-to-Completion in Seconds) Score Change from Baseline by Caffeine Level at 8-10 Hours Post-Caffeine Administration.



* 200mg and 300mg significantly lower than placebo

Repeated Acquisition

Repeated acquisition means and standard deviations by level of caffeine can be found in Table 7 (1-1.5 hours post-administration). The change from baseline measure revealed a significant ($p < 0.05$) effect for dose of caffeine to improve time-to-completion in this test at 1-1.5 hours post-administration (Figure 5). The 200 mg caffeine dose had the lowest time-to-completion in the task, followed by 300 mg, 100 mg, and then the placebo group. The 200 mg group had a significantly shorter time-to-completion of the task than did the placebo group ($p < 0.01$). There were no significant group differences for the number of incorrect responses at 1-1.5 hours post-administration, although the 200 mg and 300 mg dose groups had the lowest number of such responses (Table 7).

At 8-10 hours post drug administration, time-to-completion (change from baseline) still showed a significant dose effect ($p < 0.05$; Figure 6). Both the 200 mg and 300 mg caffeine dose had lower times-to-completion than the placebo group ($p < 0.05$). The number of incorrect responses did not differ between the groups, although the two highest caffeine doses had a smaller number of them.

Profile of Mood States and Stanford Sleepiness Scale

Means and standard deviations of mood states using the POMS may be found in Table 8 and measures of SSS in Table 9. Both tables show breakdowns at 1 hour after caffeine/placebo was consumed (i.e., when caffeine would be most active) by level of caffeine. An ANOVA was run on each POMS mood scale measure with caffeine level as the grouping factor. These ANOVAs used change from baseline scores, and showed that caffeine significantly affected feelings of fatigue (Figure 7). Fatigue increased significantly less ($p < 0.05$) in the 300 mg group compared to all other groups, which were not significantly different from one another. This effect remained at 8-10 hours post-caffeine administration (Figure 8). Overall, from Table 9 at 1 hour after caffeine ingestion, the 200 mg dose exhibited the lowest levels of tension, depression, anger, and confusion, and the highest level of vigor. The lowest level of fatigue was seen in the 300 mg group. Total mood disturbance was 10% lower (i.e., they felt better) in the 200 mg group than in the placebo group.

A dose response pattern occurred for sleepiness (Figure 9). The 300 mg dose showed the smallest increase for sleepiness from baseline, and the placebo group showed the largest increase. The 200 and 300 mg groups' levels were significantly lower than the other two groups ($p<0.05$).

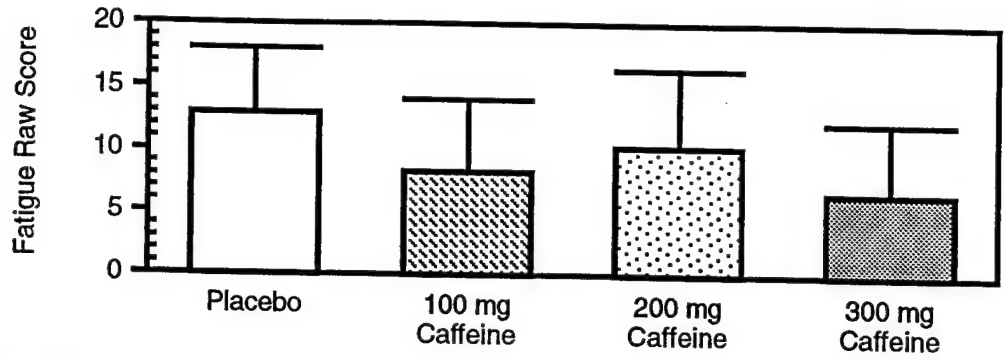
Table 8. Profile of Mood States Raw Score Measures by Level of Caffeine at 1-1.5 Hours Post-Administration in 64 BUD/S Trainees.

	PLACEBO MEAN ± S.D. (*n*=15)	100 mg CAF MEAN ± S.D. (*n*=17)	200 mg CAF MEAN ± S.D. (*n*=17)	300 mg CAF MEAN ± S.D. (*n*=15)
Tension	14.0 ± 5.3	17.1 ± 5.8	13.5 ± 3.9	16.1 ± 7.5
Depression	14.7 ± 8.0	14.0 ± 10.9	8.4 ± 5.8	13.7 ± 9.6
Anger	16.5 ± 7.3	14.0 ± 10.4	12.2 ± 8.0	16.0 ± 8.2
Vigor	6.4 ± 4.8	8.7 ± 5.2	9.4 ± 5.9	8.9 ± 6.3
Fatigue	21.6 ± 4.0	21.6 ± 5.5	21.4 ± 4.4	20.3 ± 4.4
Confusion	14.3 ± 4.0	13.1 ± 5.6	10.0 ± 4.0	11.5 ± 6.3
Total Mood	174.8 ± 23.7	171.1 ± 32.8	156.1 ± 22.1	168.8 ± 30.3

Table 9. Stanford Sleepiness Scale Scores by Level of Caffeine at 1-1.5 Hours Post-Administration in 61 BUD/S Trainees.

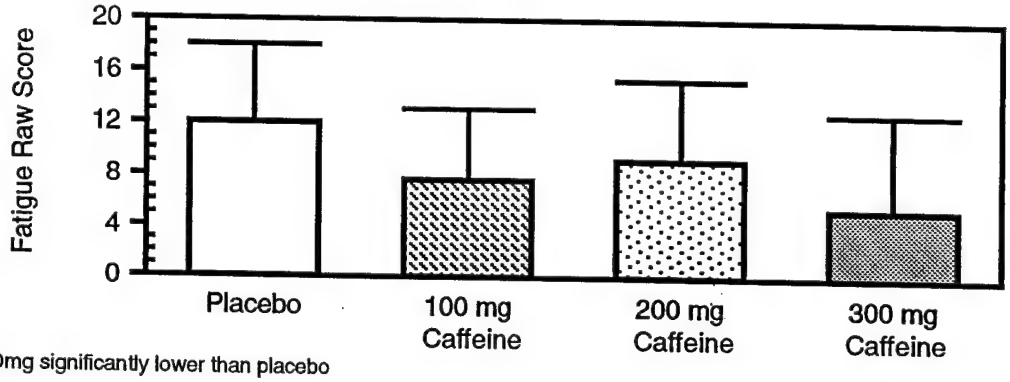
	PLACEBO MEAN ± S.D. (*n*=15)	100 mg CAF MEAN ± S.D. (*n*=15)	200 mg CAF MEAN ± S.D. (*n*=17)	300 mg CAF MEAN ± S.D. (*n*=14)
SSS	5.7 ± 0.8	5.9 ± 0.8	4.8 ± 1.6	5.2 ± 1.4

Figure 7. Profile of Mood States Fatigue Raw Score Change from Baseline by Caffeine Level at 1-1.5 Hours Post-Caffeine Administration.



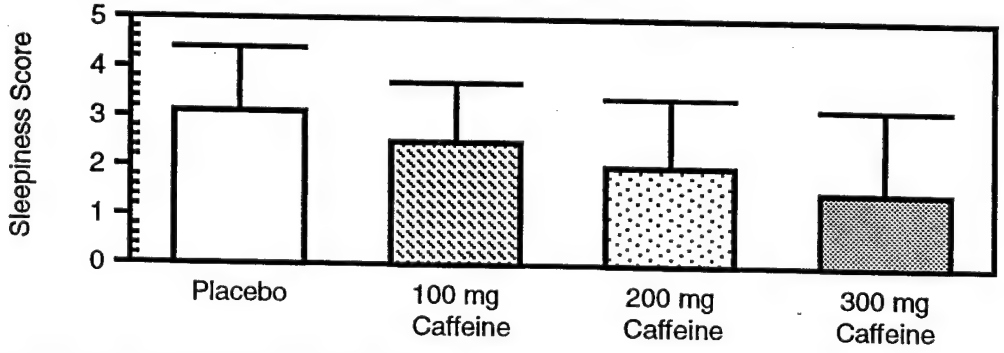
* 300mg significantly lower than placebo

Figure 8. Profile of Mood States Fatigue Raw Score Change from Baseline by Caffeine Level at 8-10 Hours Post-Caffeine Administration.



* 300mg significantly lower than placebo

Figure 9. Stanford Sleepiness Scale Score Change from Baseline by Caffeine Level at 1-1.5 Hours Post-Caffeine Administration.



* 200mg and 300mg significantly lower than placebo

Rifle Marksmanship

An ANOVA was run on each marksmanship measure with level of caffeine as a grouping factor to assess changes at the 1-1.5 hour and the 8-10 hour post-administration periods. No differences in marksmanship scores existed between conditions at either time period. An examination of change scores (change in 1-1.5 hours minus baseline, and change in 8-10 hours minus baseline) showed no significant differences between caffeine groups. However, the group that took the 200 mg dose had a 30% tighter shot group while shooting 0.8 seconds faster after taking this dose of caffeine than did the group taking the placebo. Values by dose level for the various marksmanship measures are presented in Table 10 for the 1-1.5 hours post-administration test period.

Auditory Vigilance

Auditory vigilance was recorded during midnight rations and the "Round the World" evolution, which is an approximate 12-mile paddle from the Naval Amphibious Base in San Diego Bay to the Naval Special Warfare Center on the ocean beach in Coronado. Response to the auditory stimuli showed no significant effect ($p > 0.05$) between levels of caffeine, nor was there an interaction effect. A non-significant trend may be observed in Table 11 with the placebo group responding to the auditory tone less frequently than the caffeine groups and also taking slightly longer to respond to the tone they did hear. Data were obtained up to 3.5 hours after caffeine exposure. Originally, it was scheduled to be recorded for the 8 hours between test sessions; however, by the 3.5 hour time period of data collection, less than half of the monitors were still functioning and recording data. Twelve monitors failed to record data at all. Failure to record data most likely occurred due to submersion in the water (monitors are not waterproof).

Table 10. Marksmanship Score Measures by Level of Caffeine at 1-1.5 Hours Post-Administration in 62 BUD/S Trainees.

	PLACEBO MEAN ± S.D. (*n*=14)	100 mg CAF MEAN ± S.D. (*n*=16)	200 mg CAF MEAN ± S.D. (*n*=16)	300 mg CAF MEAN ± S.D. (*n*=16)
DCM	7.3 ± 2.6	7.0 ± 3.3	7.0 ± 2.9	7.4 ± 3.2
SGT	125.8 ± 153.6	110.5 ± 184.4	88.4 ± 139.8	119.9 ± 195.5
HSGT	8.7 ± 5.4	7.9 ± 6.4	7.4 ± 5.0	8.4 ± 6.4
VSGT	9.6 ± 5.5	9.6 ± 6.4	9.2 ± 5.1	9.1 ± 6.5
STIME	8.9 ± 2.3	9.2 ± 2.6	8.1 ± 2.6	8.6 ± 3.7
MISS	1.5 ± 2.4	1.3 ± 2.4	1.1 ± 1.9	1.6 ± 2.3

Key Abbreviations: DCM = distance from center of mass (mm); SGT = shot group tightness (mm^2); HSGT = horizontal shot group tightness (mm); VSGT = vertical shot group tightness (mm); STIME = sighting time (sec); MISS = missed targets (number of)

Table 11. Auditory Vigilance Score Measures by Level of Caffeine From 1-1.5 Hours to 3.5 Hours Post-Administration in 38 BUD/S Trainees.

	PLACEBO MEAN ± S.D. (*n*=11)	100 mg CAF MEAN ± S.D. (*n*=10)	200 mg CAF MEAN ± S.D. (*n*=11)	300 mg CAF MEAN ± S.D. (*n*=6)
Percent Correct Hits	37.9 ± 19.2	46.2 ± 18.7	41.3 ± 19.6	42.3 ± 15.4
Response Time (sec)	6.7 ± 3.3	6.4 ± 1.1	6.4 ± 1.9	6.3 ± 1.6

Table 12. Hydration State Responses to Number of Times Urinated and Fluid Consumed Up to 10 Hours After Caffeine Ingestion (Includes Both Test Sessions and Hell Week Activity in Between Test Sessions).

	Placebo MEAN ± S.D. (*n*=14)	100 mg MEAN ± S.D. (*n*=16)	200 mg MEAN ± S.D. (*n*=13)	300 mg MEAN ± S.D. (*n*=15)	Total MEAN ± S.D. (*n*=58)
Number of Times Urinated	2.6 ± 1.2	2.4 ± 1.2	2.2 ± 0.9	2.5 ± 1.3	2.4 ± 1.1
Fluid Consumed (oz)	35.6 ± 17.1	31.1 ± 19.7	28.2 ± 15.2	38.1 ± 20.8	34.3 ± 19.0

Hydration State

Self-reported measures indicating the effects of caffeine on hydration state are shown in Table 12. There were no significant differences ($p > 0.05$) between caffeine groups for either the number of times volunteers reported they urinated or the amount of fluid consumed.

Subjective Effects of Caffeine

Volunteers were asked whether they thought they received caffeine or not. Most (75%) of those that did not receive caffeine were correct in their guessing that they were administered placebo. Only 51% who received caffeine correctly guessed they were administered caffeine, the highest number being in the 200 mg group. Table 13 illustrates these data.

Table 13. Subjective Prediction of Receiving Caffeine or Not by Caffeine Group.

DRUG PREDICTION	PLACEBO (*n*=16)	100 mg (*n*=17)	200 mg (*n*=15)	300 mg (*n*=15)
No Caffeine	12	9	5	9
Caffeine	4	8	10	6

Subjective assessment of whether their pill (caffeine or placebo) helped BUD/S trainees in their training and during the test session revealed significant differences between caffeine groups ($\chi^2 = 18.37$, $p < 0.05$). Of those receiving 200 mg of caffeine, 53% felt that it helped their performance. As would be expected, only one individual receiving the placebo felt that it helped his performance. Those receiving the 100 mg and 300 mg of caffeine only had one and two individuals, respectively, who felt that their performance was enhanced. A breakdown of these data by caffeine group may be seen in Table 14.

Table 14. Subjective Assessment of Drug Helping Performance or Not by Caffeine Group.

HELP PERFORMANCE	PLACEBO (*n*=16)	100 mg (*n*=17)	200 mg (*n*=15)	300 mg (*n*=15)
Neither	13	11	4	9
Helped	1	1	8	2
Hurt	0	1	1	1
Don't Know	2	4	2	3

There were no significant differences using a chi square analyses between caffeine groups on the number of subjective side effects felt (Table 15). Of the 47 individuals receiving caffeine, 7 individuals or 15% reported some negative side effect of caffeine. Symptoms that were reported included nervousness (*n*=4), blurry vision (*n*=4), dizziness (*n*=3), nausea (*n*=2), tiredness/felt a crash (*n*=2), clammy mouth (*n*=1), weak muscles (*n*=1), and felt flush in the face (*n*=1). As can be deduced, most individuals who had a side effect reported more than one.

Table 15. Subjective Assessment of Drug Having Side Effects or Not by Caffeine Group.

SIDE EFFECTS	PLACEBO (*n*=16)	100 mg (*n*=17)	200 mg (*n*=15)	300 mg (*n*=15)
No	14	13	13	11
Yes	1	3	2	2
Don't Know	1	1	0	2

EFFECTS OF SLEEP DEPRIVATION AND OPERATIONAL STRESS

Visual Vigilance

Visual vigilance measures were all significantly impaired ($p < 0.05$) 73-74 hours into Hell Week compared to baseline measures (Table 16). Hits decreased from 18 (90% Hit Rate) to 10.6 (53% Hit Rate). Response time for correct hits increased from 0.9 seconds to 1.2 seconds. Volunteers had to respond within 2 seconds or it would result in a false positive hit. False positive hits increased 181% from baseline to the first Hell Week test period. No interaction effect of caffeine existed to suggest a crash in performance. However, 8-10 hours post-pill administration (80-82 hours into Hell Week) performance was further degraded, with the increase in false positive hits being the most notable increase (49 hits to 149 hits). Hits at 8-10 hours post-pill administration were not significantly different using Tukey's test from the hit-rate observed at 1-1.5 hours post-pill administration, but false positive hits and response time both showed significant differences ($p < 0.05$) compared to both baseline and the 1-1.5 hour measures.

Four-Choice Visual Reaction Time

Reaction time measures were all significantly impaired ($p < 0.05$) at 73-74 hours (1-1.5 hours post-caffeine ingestion) and 80-82 hours (8-10 hours post-caffeine ingestion) into Hell Week from baseline measures (Table 17). No significant differences existed between the two test sessions, and no interaction effects existed. Time-out errors were affected the most as there was a 20- to 33-fold increase from baseline in the number of these type of errors present during the Hell Week test sessions.

Table 16. Visual Vigilance Score Measures Over Time in 58 BUD/S Trainees With Level of Significance.

	BASELINE MEAN ± S.D.	1-1.5 HRS MEAN ± S.D.	8-10 HRS MEAN ± S.D.	Significance
Hits Total = 20	18.0 ± 2.0	10.6 ± 5.6	8.7 ± 5.0	0.00001
Total False Positive Hits	17.7 ± 76.5	49.0 ± 128.1	149.0 ± 383.1	0.008
Response Time (Sec.)	0.9 ± 0.2	1.2 ± 0.5	1.4 ± 0.8	0.0001

Table 17. Four-Choice Reaction Time Score Measures Over Time in 58 BUD/S Trainees With Level of Significance.

	BASELINE MEAN ± S.D.	1-1.5 HRS MEAN ± S.D.	8-10 HRS MEAN ± S.D.	Significance
Correct Hits Total = 250	243.7 ± 5.2	201.2 ± 37.6	226.4 ± 23.4	0.00001
Latency Cor. Hit (ms)	531.0 ± 84.3	641.3 ± 109.3	645.7 ± 101.6	0.00001
Latency Inc. Hit (ms)	433.5 ± 174.7	492.3 ± 212.6	534.4 ± 186.6	0.02
Premature Errors (Total)	0.2 ± 0.6	2.0 ± 6.1	1.5 ± 3.7	0.03
Time-out Errors (Total)	0.4 ± 1.0	10.8 ± 16.3	13.5 ± 16.7	0.00001

Matching to Sample

Means and standard deviations for the matching to sample measures over time can be found in Table 18. Performance on all measures for this test were significantly impaired ($p < 0.05$) during Hell Week when compared to baseline measures. When considering all the trials (those with both short and long delays), number of correct responses decreased 16%, reaction time increased 42%, and time-out errors increased 950% over baseline for the first testing period (1-1.5 hours post-drug administration). Additionally, during the final test period (8-10 hours post-drug administration), correct responses, reaction time, and time-out errors were still significantly impaired from baseline. However, performance significantly improved on measures of reaction time and time-out errors at 8-10 hours post-administration when compared to results from 1-1.5 hours post-administration, but not on correct responses. A separate analysis showed that sleep deprivation affected performance at both the long and short delay.

Repeated Acquisition

Performance on the repeated acquisition test (Table 19) showed significant ($p < 0.01$) impairments over time. The first testing period (1-1.5 hours post-drug administration) showed a 23% increase in incorrect responses and a 63% increase in time-to-completion when compared to baseline. Performance was slightly worse at the 8-10 hour post-drug administration test period, with number of incorrect responses increasing 41% and time-to-completion increasing 67% over baseline. Incorrect responses were significantly higher 8-10 hours post-administration than at 1-1.5 hours post-administration; time-to-completion was not significantly different between the two testing periods.

Table 18. Matching to Sample Score Measures Over Time in 66 BUD/S Trainees with Level of Significance.

	BASELINE MEAN ± S.D.	1-1.5 HRS MEAN ± S.D.	8-10 HRS MEAN ± S.D.	Significance
Correct Responses (Tot.)	12.7 ± 2.3	10.7 ± 3.4	10.8 ± 2.8	0.00001
Reaction Time (sec)	4.5 ± 1.4	6.4 ± 2.3	5.7 ± 1.9	0.00001
Time-out Errors (Tot.)	0.2 ± 0.5	2.1 ± 3.6	1.2 ± 1.8	0.00001

Table 19. Repeated Acquisition Score Measures Over Time in 64 BUD/S Trainees with Level of Significance.

	BASELINE MEAN ± S.D.	1-1.5 HRS MEAN ± S.D.	8-10 HRS MEAN ± S.D.	Significance
Incorrect Responses	9.3 ± 4.1	11.4 ± 5.4	13.1 ± 5.0	0.00001
Time-to-Completion (sec)	21.9 ± 5.6	35.8 ± 17.6	36.6 ± 14.6	0.00001

Profile of Mood States and Stanford Sleepiness Scale

Moods were significantly poorer 73-74 hours into Hell Week compared to baseline measures. The most dramatic changes seen were increases in depression, fatigue, and confusion. All measures were significant at $p < 0.0001$. No differences were observed between 1-1.5 hours after pill administration and 8-10 hours after pill administration for any mood state. Baseline measures were performed at 1700-1900 hours, while the first measures during Hell Week test period were taken between 2200 and 2300. Means and standard deviations for the various mood states over test periods are shown in Table 20.

The SSS showed similar changes to the POMS in level of tiredness between test sessions ($p < 0.00001$). No significant difference existed for both the 1-1.5 hours and the 8-10 hours post-drug administrations, while both Hell Week measures of sleepiness were greater than baseline values ($p < 0.05$). Means and standard deviations for sleepiness measures over test periods are found in Table 21.

Table 20. Profile of Mood States Raw Score Measures Over Time in 64 BUD/S Trainees With Level of Significance.

	BASELINE MEAN ± S.D	1-1.5 HRS MEAN ± S.D.	8-10 HRS MEAN ± S.D.	Significance
Tension	9.6 ± 5.7	15.2 ± 5.8	13.1 ± 5.8	0.00001
Depression	4.5 ± 7.7	12.6 ± 9.0	10.4 ± 7.9	0.00001
Anger	7.5 ± 12.8	14.6 ± 8.6	12.0 ± 8.2	0.00001
Vigor	12.8 ± 11.8	8.4 ± 5.6	7.5 ± 5.4	0.00001
Fatigue	11.8 ± 5.9	21.2 ± 4.6	20.3 ± 5.5	0.00001
Confusion	5.7 ± 3.7	12.2 ± 5.2	12.3 ± 4.8	0.00001
Total Mood	126.3 ± 27.1	167.4 ± 27.9	160.6 ± 24.9	0.00001

Table 21. Stanford Sleepiness Scale Scores Over Time in 61 BUD/S Trainees With Level of Significance.

	BASELINE MEAN ± S.D.	1-1.5 HRS MEAN ± S.D.	8-10 HRS MEAN ± S.D.	Significance
SSS	3.1 ± 1.2	5.4 ± 1.3	5.8 ± 1.2	0.00001

Rifle Marksmanship

Rifle marksmanship was significantly ($p < 0.05$) impaired 73-74 hours into Hell Week compared to baseline measures (Table 22). Decrements included the average DCM increasing by 20% and SGT increasing 136% after the effects of Hell Week. Related to an increase in SGT, 17.5% of the targets were missed at this time period. Sighting time increased by 2.9 seconds or by 50%. The final test period occurred at 0500-0700 the following morning. It was approximately 80-82 hours into Hell Week. All marksmanship measures improved from the previous test period, but were still significantly impaired from baseline ($p < 0.05$).

Auditory Vigilance

A significant decrease ($p < 0.05$) in the number of correct hits in response to the auditory tone was seen past the 2.5 hour post-administration mark (see Table 23). There was also a significantly lower number of responses in the 1-1.5 hour post-administration time period ($p < 0.05$), due to some volunteers still taking part in other tests and not immediately responding to the tones. Therefore, using Tukey's post hoc testing, significant differences ($p < 0.05$) between the 1.5-2 hour time period and the 2-2.5 hour time period vs. the other three time periods existed. No other individual differences between time periods existed however. Response time did not show any significant differences over time.

Table 22. Marksmanship Score Measures Over Time in 62 BUD/S Trainees With Level of Significance.

	BASELINE MEAN ± S.D.	1-1.5 HRS MEAN ± S.D.	8-10 HRS MEAN ± S.D.	Significance
DCM	6.0 ± 2.3	7.2 ± 3.0	6.5 ± 2.4	0.01
SGT	46.8 ± 38.6	110.7 ± 166.7	63.6 ± 89.9	0.008
HSGT	5.8 ± 3.3	8.1 ± 5.7	6.9 ± 4.1	0.01
VSGT	6.5 ± 3.2	9.4 ± 5.8	7.6 ± 3.7	0.0009
STIME	5.8 ± 1.8	8.7 ± 2.8	7.6 ± 2.3	0.0001
MISS	0.6 ± 1.2	1.4 ± 2.2	0.6 ± 1.5	0.01

Key Abbreviations: DCM = distance from center of mass (mm); SGT = shot group tightness (mm^2); HSGT = horizontal shot group tightness (mm); VSGT = vertical shot group tightness (mm); STIME = sighting time (sec); MISS = missed targets (number of)

Table 23. Auditory Vigilance Score Measures Over Time From 1 Hour to 3.5 Hours Post-Caffeine Administration in 38 BUD/S Trainees with Level of Significance.

	1-1.5 HRS MEAN ± S.D.	1.5-2 HRS MEAN ± S.D.	2-2.5 HRS MEAN ± S.D.	2.5-3 HRS MEAN ± S.D.	3-3.5 HRS MEAN ± S.D.	Significance
Percent Correct Hits	29.3 ± 22.8	67.4 ± 28.0	59.8 ± 27.6	28.9 ± 23.9	23.4 ± 27.5	0.00001
Response Time (sec)	5.9 ± 4.2	6.1 ± 3.3	7.3 ± 3.9	7.3 ± 5.1	5.8 ± 5.3	NS

DISCUSSION

VIGILANCE

Visual vigilance tasks have been shown to be some of the most sensitive performance tasks to be affected by sleep deprivation. As little as 24 hours without sleep can impair visual vigilance (Opstad, Ekanger, Nummestad et al., 1978). The effects of sleep deprivation associated with Hell Week showed large decrements in detecting a target, as well as increases in false positive detections as time passed for both visual and auditory measures of vigilance. Response time of correct detections for the vigilance task was markedly longer than in the non-sleep-deprived condition. The implications for military tasks such as flying of aircraft, detection of the enemy, and monitoring a radar screen are apparent. Time urgent decisions will take longer to be made, and errors associated with these decisions will be more prevalent, compromising performance. Therefore, the effects of sleep deprivation can be life threatening to those involved in combat.

The use of caffeine significantly minimized the adverse effects of the multi-stressor environment of Hell Week on vigilance. The average rate of targets detected on the visual vigilance task in a rested, non-stressed baseline condition was 90%. When sleep was deprived during Hell Week, the average target detection rate without the aid of caffeine was 39.5%. The use of 300 mg of caffeine enabled these BUD/S trainees to detect 61% of the targets while sleep was deprived for 73-74 hours. Response time averaged 1 second in the rested baseline condition. It increased only 0.1 second during the sleep-deprived Hell Week testing period when using 300 mg of caffeine. In contrast, response time was 0.5 seconds slower during Hell Week without the use of caffeine. Both of these vigilance measures show a linear dose-dependent response pattern, with the largest decrements seen in the group administered the placebo and the smallest decrements seen in the group administered the 300 mg dose of caffeine.

These results are supported by similar previous research on the use of caffeine to improve vigilance. Lieberman and colleagues found in non-sleep-deprived

individuals that auditory and visual vigilance correct hits were improved by the administration of as little as 64 mg of caffeine (Fine, Kobrick, Lieberman et al., 1994; Lieberman, Wurtman, Emde et al., 1987; Lieberman, Wurtman, Garfield et al., 1987). Visual vigilance such as target scanning performance was enhanced with caffeine in average doses of as 200 mg (Baker and Theologus, 1972; Childs, 1978), but in those who regularly consume no or very little caffeine, higher doses (400 mg) can actually have a detrimental effect (Childs, 1978).

In a double-blind study, response time and number of errors responding to an auditory vigilance task were significantly lower after consuming two doses of 250 mg of caffeine (at 0900 hours and again at 1300 hours) (Zwyguhizen-Doorenbos, Roehrs, Lipschutz et al., 1990). Furthermore, even after the effects of caffeine should have worn off a day later, the performance of those receiving caffeine was not different from their performance while receiving caffeine, but was significantly better than those receiving placebo. Zwyguhizen-Doorenbos, Roehrs, Lipschutz et al. (1990) attributed this to the phenomenon of a conditioning effect of caffeine to other contextual stimuli present when administered caffeine. Two alternative hypotheses are that residual caffeine existed in the system or that the administration of caffeine in some way altered the circadian rhythm of sleepiness/alertness. This finding, if true, could help immeasurably in improving soldiers' performance during periods of long sustained operations. It also helps dispel a commonly held belief that performance will "crash" as caffeine wears off.

Borland, Rogers, Nicholson et al. (1986) found that caffeine alleviated, to a small extent, the fatigue associated with continuous work on a vigilance task (9 hours) and the circadian effect of performing that task during the 0000-0800 hour time period. This conclusion is particularly relevant to why the use of caffeine might be important to combat troops whose activities often take place at night and during the early morning hours under the cover of darkness. A number of studies have reported the ergogenic effects of caffeine in the laboratory or in more controlled environments as evident from the previous research cited. The present research demonstrates the beneficial effects of caffeine in improving vigilance under the most extreme sleep-deprived and mental and physical stresses reported to date. These findings are particularly relevant to war fighters as they show the beneficial effects of caffeine in a scenario that is as close to

actual combat as can be developed.

REACTION TIME

Reaction time progressively lengthened in previous studies of sleep deprivation (Angus, Heslegrave, and Myles, 1985; Williams, Lubin, and Goodnow, 1959). The results of this study show the same effect with all measures of reaction time affected by sleep deprivation. There were no differences between the two test sessions, however. Caffeine improved performance on the four-choice reaction time test; there was a smaller decrement in correct hits when sleep deprived as compared to the placebo condition. There was a linear dose-dependent response pattern with the smallest decrement seen in the 300 mg group and the largest seen in the placebo group. These results confirm previous work on the beneficial effects of caffeine with respect to reaction time (Jacobson and Edgley, 1987; Lieberman, Wurtman, Emde et al., 1987; Lieberman, Wurtman, Garfield et al., 1987; Roache and Griffiths, 1987).

COGNITIVE TASKS

Sleep deprivation impairs cognitive performance and the ability to do useful mental work declines by 25% for every successive 24 hours that an individual is awake (Belenky, Penetar, Thorne et al., 1994). Sleep deprivation degrades the most complex mental functions, including the ability to understand, adapt, and plan under rapidly changing circumstances. During sleep deprivation, performance declines, but it usually declines in such a way as to preserve the accuracy of response at the expense of speed (Belenky, Penetar, Thorne et al., 1994). These changes in speed stem primarily from an increase in the frequency and duration of lapses (Williams, Lubin and Goodnow, 1959). Sleep loss affects mainly resource-limiting factors (number of attempted trials), rather than data-limiting factors (performance accuracy) (Mikulincer, Babkoff, and Caspy, 1989). However, this effect has also been shown to vary with the properties of the task; speed is affected on subject-paced tasks, while errors are affected on experimenter-paced tasks (Williams, Lubin and Goodnow, 1959). Therefore, it is not surprising that the cognitive task of matching to sample in

this study showed a significant decrease in the number of correct responses in addition to increases in reaction time and time-out errors (lapses), since the subject was required to respond within 15 seconds. The repeated acquisition task also yielded an increase in time-to-completion as well as incorrect responses with sleep deprivation, possibly because of the monotonous and repetitive qualities of this test. Errors under sleep-loss conditions have been shown to increase as a task continues without interruption and without a change in the stimulus-response conditions (Williams, Lubin and Goodnow, 1959).

Matching to Sample

Previous studies (Ahlers, Thomas, Schrot et al., 1994) have found that exposure to another stressor, cold ambient air (2-5°C), for periods of even as short as 1 hour produces reliable and robust impairment of working memory, as determined by a delayed matching to sample test similar to the one used in the current study. Deleterious effects of sleep deprivation, similar to those seen with cold stress, were observed in this study as percent correct matches decreased with 73-74 and 80-82 hours of sleep deprivation.

Sleep deprivation affected performance at both the long and short delay in this study. When volunteers performed the delayed matching to sample task in the last 30 minutes of a 60-90 minute exposure session to 4°C, matching accuracy at 8 and 16 second delays was impaired, while matching accuracy at 2 seconds was unimpaired by the cold stress. Ahlers, Thomas, Schrot et al. (1994) interpreted this result as indicative that moderate levels of exposure to cold stress did not impair the ability of an individual to encode the stimulus into memory, but specifically affected memory retention over time. Furthermore, they stated that in cases in which performance at the shorter delay times is also decreased, as was the case in this study, it is generally agreed that the initial encoding of information into short-term memory is impaired (Ahlers, Thomas, Schrot et al., 1994; Bushnell, 1990). Another study by Ahlers, Shurtleff, Schrot et al. (1993) using animals observed that a longer exposure to cold stress often produces impaired performance after both short and long delays, as was observed in the present study.

It appears that the sleep-deprivation stressor used here was severe enough to affect both encoding and retention of information in memory. Under these conditions, it is more difficult to reverse these impairments with treatments such as caffeine. Shurtleff, Thomas, Schrot et al. (1994) showed that tyrosine, a catecholamine precursor that can alleviate many of the deleterious effects of acute stress, was only effective under conditions in which there was a substantial cold-induced decrement only at the longest delay time (16 second), not the shorter delay. Similar results were obtained with caffeine, since it was not effective in altering performance (including correct responses, time-out errors, and reaction time) that was impaired at both the short and long delay. It appears that the sleep-deprivation stressor may have been too severe for caffeine to produce beneficial effects in the cognitive aspects of the matching to sample test. However, caffeine (up to 600 mg) was also not effective in another study assessing matching to sample performance, with a shorter sleep-deprivation period, ranging from 48 to 64.5 hours (Penetar, McCann, Thorne et al., 1994). Therefore, the lack of beneficial effects of caffeine on complex cognitive performance, as measured by the matching to sample test, could also be due to the fact that caffeine has shown inconclusive results (Lieberman, 1992; Meiselman and Lieberman, 1994) or no improvement (Battig, Buzzi, Martin et al., 1984) on memory and learning tasks.

Repeated Acquisition

In the repeated acquisition procedure, subjects are required to learn a new sequence of appropriate responses. For this reason, the repeated acquisition task places a great demand on an individual's ability to learn new information (Ahlers, Thomas, Schrot et al., 1994). It takes many trials for a subject to learn the new sequence and makes the repeated acquisition task particularly sensitive in revealing learning (encoding) deficits. Tyrosine has not demonstrated consistent effects in modifying cold-induced decrements in the ability to learn a new response sequence as part of the repeated acquisition task, as was shown above with the encoding deficits in the matching to sample test (Ahlers, Thomas, Schrot et al., 1994). In the present study, caffeine also did not affect incorrect responses, and this result is consistent with the findings from other studies that the effect of caffeine on complex cognitive

performances requiring memory or learning has shown inconclusive results (Lieberman, 1992; Meiselman and Lieberman, 1994) or no improvement (Battig, Buzzi, Martin et al., 1984).

However, caffeine was effective in improving time-to-completion in the repeated acquisition task. Athough cognitive performance may not be affected by caffeine, vigilance performance is usually enhanced (Meiselman and Lieberman, 1994). Caffeine appears to improve performance on tasks that require sustained attention (Meiselman and Lieberman, 1994) rather than cognitive functions (Battig, Buzzi, Martin, and Feierabend, 1984). The ability to pay attention is critical to complete the repeated acquisition test. Additionally, repeated acquisition is a task where the same sequence of keys is pressed over and over, possibly leading to boredom. Caffeine has been shown to reduce the degradation of performance induced by fatigue or boredom (Dews, 1984; Weiss and Laties, 1962).

MOOD AND SLEEPINESS

Mood changes as a result of sleep deprivation were observed in all six POMS mood factors (tension, depression, anger, vigor, fatigue, and confusion). When sleep-deprived for 73-74 hours, individuals felt less vigorous and had increased feelings of the five negative mood states. The degree of mood disturbance was notably greater than that observed by Penetar, McCann, Thorne et al. (1994) after 47 hours of sleep deprivation. Comparisons of mood scores using the POMS between studies are shown in Table 24. While the feelings of vigor were not different between studies (both are low), all other mood states were felt subjectively more in the present study, most likely as a result of the stressful nature of Hell Week, which would especially cause feelings of anger (agitation), fatigue, and confusion. The length of time without adequate sleep would also likely increase all the negative affective mood states.

Opstad, Ekanger, Nummestad et al. (1978) also found similar mood changes as a result of sleep deprivation. Their study was similar to this one as they examined the performance of cadets taking part in Norwegian Ranger Training. The associated physical work, caloric deficits and psychological stress that the training imposed

Table 24. Comparison of POMS Mood States Scores After 47 Hours (Previous Study by Penetar, McCann, Thorne et al., 1994) and After 73-74 Hours of Sleep Deprivation (Present Study).

	47 Hr Sleep Deprivation Penetar Study	73-74 Hr Sleep Deprivation Current Study
Tension	7.4	15.2
Depression	4.2	12.6
Anger	2.9	14.6
Vigor	8.0	8.4
Fatigue	14.3	21.2
Confusion	8.9	12.2

combined to induce negative moods. The importance of observing mood alterations due to a stressor such as sleep deprivation is important for military leaders or work supervisors because mood changes are often a warning signal to performance changes that may occur later with greater consequences (Opstad, Ekanger, Nummestad et al., 1978).

The use of caffeine (100, 200, or 300 mg) allowed for a significantly smaller increase in fatigue scores than in the placebo condition. No other mood states differed in this study. Penetar, McCann, Thorne et al. (1993) found that fatigue and vigor differed in a placebo group vs. caffeine in doses of 150, 300, and 600 mg in sleep-deprived individuals. In their study, confusion for the 150 mg group was lower than for the placebo group, but the 300 and 600 mg groups did not differ. No differences in the other mood scales were observed in their study (Penetar, McCann, Thorne et al., 1993). Other studies have shown varying results. An increase in vigor was observed when caffeine was administered to non-sleep-deprived individuals (Lieberman, Wurtman, Emde et al., 1987). Lieberman (1988) also noted a reduction in anxiety and depression with lower doses of 64 and 128 mg in the morning. Other

studies, however, have demonstrated no changes in mood (Lieberman, Wurtman, Garfield et al., 1987; Loke, Hinrichs and Ghoneim, 1985).

Caffeine has been shown to decrease sleepiness as measured by the SSS in non-sleep-deprived individuals. In this study, the SSS level of sleepiness changed from a baseline score of 3.1 to scores of 5.4 and 5.8 (73-74 and 80-82 hours, respectively, after Hell Week began). The use of caffeine demonstrated a dose response effect, where the more caffeine administered, the smaller was the increase in level of sleepiness or lack of alertness. Our levels of sleepiness followed the same pattern as the results of Penetar, McCann, Thorne et al. (1993, 1994), except that our levels of sleepiness were greater. This is to be expected, since our level of sleep deprivation and physical stress was much greater than that of their laboratory study. Angus, Heslegrave, and Myles (1985) also saw increased levels of sleepiness on the SSS to levels of 4.0. They examined differences in exercise vs. no exercise in sleep-deprived individuals and found no differences between exercise conditions. Their exercise condition was much milder than those imposed on the BUD/S volunteers. However, it is still probably safe to say that an increase in SSS scores is related primarily to the amount of sleep deprivation and not to the exercise. Anecdotal evidence observed and gained by talking to the BUD/S instructors suggests that it is in the transition from quiet periods (such as meal times) to more physically active evolutions, as was the case in this study, that feelings of sleepiness and fatigue tend to be the most problematic.

RIFLE MARKSMANSHIP

Sleep deprivation caused a significant decrease in accuracy and an increase in time to sight the target. Haslam (1982), in a previous study with infantry-men, reported that shooters in the prone position had a 25% decrement in the number of pop-up targets hit between 48 and 92 hours of sleep deprivation. When shooting a cluster of shots self-paced at a stationary target, no deterioration from a well-rested state was seen up to 90 hours without sleep; however, when shooting at targets that appeared at random locations on a firing range, then performance dropped to below 10% of baseline (Haslam and Abraham, 1987). This study resembled the pop-up

target study of Haslam (1982), as there were both speed and accuracy aspects. Volunteers had to react to the red signal-to-shoot light. These results, combined with previous research (Haslam, 1982; Opstad, Ekanger, Nummestad et al., 1978), support the premise that non-self-paced marksmanship tasks are vulnerable to the effects of sleep deprivation. Research with various types of competitive shooters (smallbore rifle, rapid fire, free pistol, fullbore rifle, and clay pigeons) found degradation could be caused by the effects of sleep deprivation that are associated with time zone shifts when travelling to international competitions (Antal, 1975). The single most important factor affecting the marksmanship decrements was the inability to concentrate. Other problems cited include lack of coordination, muscular weakness and tremor, loss of reaction speed, loss of visual acuity, and lassitude and early fatigue, cited in that order (Antal, 1975). All of these causes are likely to contribute to the decrements seen in the present study. However, prone shooters (similar to the present study) were most affected by their inability to concentrate and by variations in visual acuity, which also could have been the leading cause in this study, especially when the subjective mood state results are considered.

Froberg, Karlsson, Levi et al. (1975) found that shooting performance on the first night without sleep was relatively accurate. However, once the effects of sleep deprivation are evident, marksmanship performance closely paralleled circadian rhythms and adrenaline excretions, with performance being poorest between midnight and 0500. In our study, volunteers were already sleep-deprived by the time of our first test session, which was at the beginning of a low circadian cycle. Based on Froberg, Karlsson, Levi et al.'s (1975) research, it is not surprising that there was a slight increase in shooting performance during the second test session, which occurred between 0500 and 0700.

The effects of sleep deprivation on rifle marksmanship were not significantly improved by administering caffeine. Johnson (1991), and Johnson and Merullo (1996) found that administering caffeine in a sentry duty scenario did not improve marksmanship accuracy (total targets hit), but did improve target detection time. Johnson's studies used brief and infrequent stimuli (that of detecting a simulated enemy soldier) at a rate of 12 per 30 minutes for 3 hours at a simulated distance of 250 meters. The present study's marksmanship task was not a vigilance task, as a

target was presented to the shooter on average once every 30 seconds at a simulated distance of 50 meters. In Johnson's studies, the volunteer had to search the simulated horizon for target presentation. In the present study, the shooter only had to react to the target light presentation in a known standard location.

One reason caffeine may not have improved performance was the high standard deviations in the various shooting parameters. These high standard deviations are due to missed shots, and inter- and intra-subject variability when shooting while sleep-deprived and under the influence of other Hell Week stressors. These large intra-subject variations may have masked any real differences that could have occurred. These volunteers had not received extensive marksmanship or other small arms training as may be observed from Table 2. This training takes place in Phase 3 of BUD/S training. Additionally, time constraints prevented extensive training in the practice sessions of this experiment.

While the administration of caffeine did not improve marksmanship performance when sleep-deprived, a trend towards improved accuracy as determined by SGT was seen with the 200 mg dose. More importantly, the concern that muscle tremor associated with caffeine use (Loke, Hinrichs and Ghoneim, 1985; Svensson, Persson and Sjoberg, 1980) would disrupt shooting accuracy was not evident. One reason may have been that the prone shooting position was used, which is more stable and a simpler task (Tharion, Montain, O'Brien et al., 1997). Loke, Hinrichs, and Ghoneim (1985) reported that caffeine-induced hand tremors are more apparent as task difficulty increases. With regard to rifle marksmanship, shooting in the standing unsupported position may have been more susceptible to potential negative effects of caffeine-induced tremor. Nevertheless, using caffeine improved vigilance (discussed below) while not impairing marksmanship. This combination of improving vigilance while not impairing marksmanship is important for today's combat soldier who is deprived of sleep, but must still maintain proficiency in the use of small arms. These combined results help to confirm Haslam's conclusion that "shooting skill does not deteriorate but that attention does; and while in the event of war, motivation to see and fire at the enemy will be high, vigilance under the conditions of sleep loss will certainly deteriorate over time" (Haslam, 1982, p. 174).

HYDRATION STATE

Some research has shown that caffeine has thermogenic and diuretic effects (Curaldo and Robertson, 1983). No effects were seen in hydration levels as assessed by self-reported fluid intake and urine output in the present study. These findings are in agreement with previous research that showed no effect in hydration state and associated parameters as a result of caffeine ingestion (Falk, Burstein, Rosenblum et al., 1990; Gordon, Myburgh, Druger et al., 1982; Toner, Kirkendall, Delio et al., 1982).

SUBJECTIVE EFFECTS OF CAFFEINE

Previous research (Loke, Hinrichs, and Ghoneim, 1985) has shown that subjective detection of caffeine was significant, and the greater the dose, the more accurate the volunteer was able to predict that they received caffeine. The present results showed that volunteers were able to detect that they did not receive caffeine when they actually did not. However, when they did receive caffeine, many did not think that they received it. One possibility is that the stimulant effects of caffeine could not be effectively felt because of the depth of fatigue and tiredness experienced by undergoing the physical and mental stresses of Hell Week with an individual deprived of sleep for up to 82 hours.

The majority of those receiving the 200 mg of caffeine felt that it helped their performance. Of the 46 individuals receiving some level of caffeine, only 3 felt that it hurt their performance in some way. There were also very few negative side effects reported, the most common were blurry vision and nervousness (n = 4).

CONCLUSIONS

Caffeine administration had beneficial effects on a variety of behavioral parameters and mood states.

1. The use of caffeine boosted both speed and accuracy components of visual vigilance performance in sleep-deprived, operationally stressed BUD/S trainees.

2. Decision-making tasks requiring sustained attention, such as the four-choice reaction time test (pressing the correct key) and the repeated acquisition test (learning a certain sequence of instructions), while sleep-deprived tasjs are done faster and more accurately when caffeine is taken.

3. The use of caffeine did not produce tremors that could disrupt marksmanship performance. Although not significant, the smallest marksmanship decrements (using SGT as the accuracy measure) while sleep deprived were in those receiving the 200 mg dose.

4. Feelings of fatigue during Hell Week were minimized by taking caffeine.

5. Those taking caffeine felt more alert than those who did not have caffeine.

6. Consumption of caffeine did not result in any increases in urination frequency or increases in thirst to consume more fluids.

7. Fifty-three percent of those consuming the 200 mg dose felt the pill they took helped their performance in the few hours after receiving it compared to one individual (6.3%) in the placebo group who thought the pill helped his performance. Sixty-seven percent of those receiving the 200 mg caffeine dose correctly predicted that they received caffeine.

RECOMMENDATIONS

Based on the results of this study, it is recommended that 200 mg of caffeine be used to improve mental performance caused by sleep deprivation and simulated combat stress. This dose improves mental performance, has a positive subjective effect, and does not pose the physiological or psychological risks associated with higher doses.

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APPENDICES

Table A1. Average Soft Drink Consumption During Regular Duty by Caffeine Group.

Soft drink: cola type	PLACEBO (N=13)		100 MG CAFFEINE (N=16)		200 MG CAFFEINE (N=13)		300 MG CAFFEINE (N=15)		OVERALL (N=57)	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
None	7	54	5	33	4	40	3	21	19	37
12oz. 1-5 times per week	4	31	5	33	3	30	9	64	21	40
12oz. 2 times per day	--	--	--	--	1	10	1	7	2	4
12oz. 2-4 times per month	--	--	2	13	--	--	--	--	2	4
12oz. 7 times per year	--	--	--	--	1	10	--	--	1	2
16oz. 1 time per day	1	8	--	--	--	--	1	7	2	4
16oz. 1-4 times per week	1	8	3	20	1	10	--	--	5	10
Soft drink: Dr. Pepper										
None	8	67	9	60	10	77	10	71	37	69
12oz. 1-3 times per week	2	17	4	27	--	--	2	14	8	15
12oz. 1-2 times per month	1	8	1	7	1	8	1	7	4	8
12oz. 6 times per year	--	--	--	--	1	8	--	--	1	2
16oz. 1-5 times per week	1	8	1	7	1	8	1	7	4	8

Table A1 (Continued). Average Soft Drink Consumption During Regular Duty by Caffeine Group.

Soft drink: Mr. Pibbs	Placebo (N=13) N	Percent	100 mg Caffeine (N=16) N	Percent	200 mg Caffeine (N=13) N	Percent	300 mg Caffeine (N=15) N	Percent	Overall (N=57) N	Percent
None	10	83	14	93	13	100	14	93	51	93
12oz. 1 time per week	--	--	1	7	--	--	--	--	1	2
12oz. 1-2 times per month	1	8	--	--	--	--	1	7	2	4
16oz. 1 time per week	1	8	--	--	--	--	--	--	1	2
Soft drink: Big Red										
None	12	92	16	100	12	92	14	93	54	95
12oz. 1 time per week	--	--	--	--	--	--	1	7	1	2
12oz. 1 time per year	--	--	--	--	1	8	--	--	1	2
16oz. 1 time per month	1	8	--	--	--	--	--	--	1	2

Table A1 (Continued). Average Soft Drink Consumption During Regular Duty by Caffeine Group.

Soft drink: Mountain Dew	Placebo (N=13) N	Percent	100 mg Caffeine (N=16) N	Percent	200 mg Caffeine (N=13) N	Percent	300 mg Caffeine (N=15) N	Percent	Overall (N=57) N	Percent
None	10	77	9	64	10	77	10	77	39	72
12oz. 1-4 times per week	--	--	4	29	1	8	4	28	9	17
12oz. 1 time per month	--	--	--	--	1	8	--	--	1	2
16oz. 2-3 times per week	1	8	1	7	1	8	--	--	3	6
16oz. 1-7 times per month	2	15	--	--	--	--	--	--	2	4
Soft drink: Mello Yellow										
None	10	83	16	100	12	92	14	93	52	93
12oz. 1 time per month	1	8	--	--	--	--	1	7	2	4
16oz. 1 time per month	1	8	--	--	--	--	--	--	1	2
16oz. 7 times per year	--	--	--	--	1	8	--	--	1	2

Table A2. Average Tea Consumption During Regular Duty by Caffeine Group.

Tea: brewed	Placebo (N=13)		100 mg Caffeine (N=16)		200 mg Caffeine (N=13)		300 mg Caffeine (N=15)		Overall (N=57)	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
None	12	92	13	81	13	100	12	80	50	88
3 cup/mug per week	--	--	1	6	--	--	--	--	1	2
1-3 cup/mug per month	--	--	1	6	--	--	3	20	4	7
4-7 cup/mug per year	1	8	1	6	--	--	--	--	2	4
Tea: instant										
None	12	92	16	100	13	100	12	80	53	93
3-4 cup/mug per month	1	8	--	--	--	--	1	7	2	4
4 cup/mug per week	--	--	--	--	--	--	1	7	1	2
4 cup/mug per year	--	--	--	--	--	--	1	7	1	2

Table A2 (continued). Average Tea Consumption During Regular Duty by Caffeine Group.

Tea: iced	Placebo (N=13)		100 mg Caffeine (N=16)		200 mg Caffeine (N=13)		300 mg Caffeine (N=15)		Overall (N=57)	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
None	11	85	6	40	8	62	8	53	33	59
1-4 8oz. per week	--	--	1	7	--	--	3	20	4	7
2 8oz. per day	--	--	--	--	1	8	--	--	1	2
2 12oz. per day	1	8	--	--	--	--	--	--	1	2
1-7 12oz. per week	1	8	6	40	4	31	--	--	11	20
2-7 12oz. per month	--	--	2	13	--	--	4	27	6	11
Tea: ration										
None	13	100	16	100	13	100	15	100	57	100

Table A3. Average Coffee Consumption During Regular Duty by Caffeine Group.

Coffee: brewed	PLACEBO (N=13)		100 MG CAFFEINE (N=16)		200 MG CAFFEINE (N=13)		300 MG CAFFEINE (N=15)		OVERALL (N=57)	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
None	8	67	9	60	7	58	5	33	29	54
1-6 cup/mug per day	3	25	--	--	2	17	2	13	7	13
1-5 cup/mug per week	--	--	2	13	2	17	5	34	9	17
1-3 cup/mug per month	1	8	2	13	1	8	2	13	6	11
4-7 cup/mug per year	--	--	2	13	--	--	1	7	3	6
Coffee: instant										
None	11	85	15	94	11	92	15	100	52	93
1-2 cup/mug per day	1	8	--	--	1	8	--	--	2	4
3 cup/mug per week	1	8	--	--	--	--	--	--	1	2
2 cup/mug per month	--	--	1	6	--	--	--	--	1	2
Coffee: MRE										
None	12	92	16	100	13	100	15	100	56	98
2 packages per month	1	8	--	--	--	--	--	--	1	2

Table A4. Average Chocolate Consumption During Regular Duty by Caffeine Group.

Cocoa: chocolate milk	Placebo (N=13)		100 mg Caffeine (N=16)		200 mg Caffeine (N=13)		300 mg Caffeine (N=15)		Overall (N=57)	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
None	8	67	8	50	11	92	7	50	34	63
1-2 cup/mug per day	1	8	3	19	--	--	3	21	7	13
1-3 cup/mug per week	3	25	4	25	1	8	1	7	9	17
1-3 cup/mug per month	--	--	1	6	--	--	3	21	4	8
Cocoa: hot chocolate										
None	8	67	10	63	11	85	10	67	39	70
1 cup/mug per day	--	--	1	6	--	--	--	--	1	2
1-2 cup/mug per week	1	8	1	6	1	8	--	--	3	5
1-5 cup/mug per month	2	17	2	13	--	--	2	13	6	11
3-7 cup/mug per year	1	8	2	13	1	8	3	21	7	13
Cocoa: MRE cocoa mix										
None	13	100	15	94	13	100	15	100	56	98
1 package per month	--	--	1	6	--	--	--	--	1	2

Table A4 (continued). Average Chocolate Consumption During Regular Duty by Caffeine Group.

Candy: milk chocolate	Placebo (N=13)		100 mg Caffeine (N=16)		200 mg Caffeine (N=13)		300 mg Caffeine (N=15)		Overall (N=57)	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
None	4	31	5	33	3	27	3	21	15	28
1oz. 1-3 times per day	3	23	4	27	3	27	4	29	14	21
1oz. 1-6 times per week	5	39	4	27	4	36	6	43	19	36
1oz. 4-7 times per month	1	8	2	13	--	--	1	7	4	8
1oz. 4 times per year	--	--	--	--	1	9	--	--	1	2
Candy: dark chocolate										
None	12	92	11	69	10	77	10	71	43	77
1oz. 1-2 times per week	1	8	3	19	2	15	3	21	9	16
1oz. 1-5 times per month	--	--	2	13	--	--	1	7	3	5
1oz. 2 times per year	--	--	--	--	1	8	--	--	1	2

Table A4 (continued). Average Chocolate Consumption During Regular Duty by Caffeine Group.

Candy: M&M	Placebo (N=13)		100 mg Caffeine (N=16)		200 mg Caffeine (N=13)		300 mg Caffeine (N=15)		Overall (N=57)	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
None	11	85	12	75	11	92	15	100	49	88
2-3 packages per week	1	8	1	6	--	--	--	--	2	4
1-3 packages per month	--	--	3	19	1	8	--	--	4	7
4 packages per year	1	8	--	--	--	--	--	--	1	2
Candy: Ration brownie										
None	12	92	13	81	12	92	15	100	52	91
2 packages per week	--	--	1	6	--	--	--	--	1	2
3 packages per month	--	--	1	6	--	--	--	--	1	2
2-5 packages per year	1	8	1	6	1	7	--	--	3	5
Candy: other										
None	11	85	12	75	11	100	10	71	44	82
1-3 times per day	1	8	1	6	--	--	2	14	4	8
1-7 times per week	1	8	3	19	--	--	2	14	6	11

Table A5. Average Tobacco Usage During Regular Duty by Caffeine Group.

Tobacco Consumption	Placebo (N=13) N	Percent	100 mg Caffeine (N=16) N	Percent	200 mg Caffeine (N=13) N	Percent	300 mg Caffeine (N=15) N	Percent	Overall (N=57) N	Percent
Smoke/Chew Tobacco	4	31	3	19	2	15	1	7	10	18
Per day consumption	(N=4) $\bar{X}$	SD	(N=3) $\bar{X}$	SD	(N=2) $\bar{X}$	SD	(N=1) $\bar{X}$	SD	(N=10) $\bar{X}$	SD
Cigarettes	–	–	–	–	–	–	–	–	–	–
Cigars	–	–	–	–	–	–	–	–	–	–
Pipe smokes	–	–	–	–	–	–	–	–	–	–
Chews	3.0	1.8	1.3	0.6	2.5	2.1	4.0	–	2.5	1.6
Age when first smoked	(N=10) N	Percent	(N=9) N	Percent	(N=9) N	Percent	(N=8) N	Percent	(N=36) N	Percent
Never smoked	10	100	9	100	8	89	7	88	34	94
16 years old	–	–	–	–	–	–	1	13	1	3
18 years old	–	–	–	–	1	11	–	–	1	3
Time since quitting	(N=9) N	Percent	(N=13) N	Percent	(N=7) N	Percent	(N=7) N	Percent	(N=36) N	Percent
Not applicable	9	100	10	77	4	57	4	57	27	75
Less than one (1) year	–	–	–	–	1	14	1	14	2	6
More than one (1) year	–	–	3	23	2	29	2	29	7	19

Table A6. Drug Usage by Caffeine Group.

Drug Usage	Placebo (N=13)		100 mg Caffeine (N=16)		200 mg Caffeine (N=13)		300 mg Caffeine (N=15)		Overall (N=57)	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
Currently taking medication regular	--	--	--	--	2	15	--	--	2	4
Allergic reaction to any drug	--	--	2	13	--	--	--	--	2	4

Medications Taken Regularly Two or More Times Per Week	Placebo (N=1)		100 mg Caffeine (N=1)		200 mg Caffeine (N=1)		300 mg Caffeine (N=1)		Overall (N=4)	
	N	Percent	N	Percent	N	Percent	N	Percent	N	Percent
Aspirin	1	100	1	100	--	--	--	--	2	50
Anacin	1	100	--	--	--	--	--	--	1	25
Ibuprofin	--	--	--	--	1	100	1	100	2	50
Sudafed	--	--	1	100	--	--	1	100	2	50

DEMOGRAPHIC CAFFEINE AND TOBACCO QUESTIONNAIRE

1. Subject Number: _____

2. What was your age on your last birthday? _____ (yrs)

3. Height: _____ (feet:inches)

4. Weight: _____ (pounds)

5. What is your military rank? _____

6. What ethnic group do you belong to?
   1. African American _____
   2. American Native _____
   3. Asian _____
   4. Hispanic _____
   5. White _____
   6. Other (please specify) _____

7. Time in the military _____ (yrs:months)

8. Do you or have you shot a rifle or pistol recreationally (e.g., you hunt or belong to a gun club)?
   yes ____ no _____ (Please check appropriate box)

9. Last Basic Rifle Marksmanship Qualification Score _____
   (Leave Blank If You Have Never Been Tested)

10. Approximate number of hours you sleep per night if you are on your own sleep schedule _____ (hrs)

11. Do you now smoke or chew tobacco? yes _____ no _____

12. Number of cigarettes smoked per day _____

13. Number of cigars smoked per day _____

14. Number of pipe smokes per day _____

15. Number of tobacco chews per day _____

16. How old were you when you started smoking? _____ (yrs old)
(Enter "0" if you never smoked)

17. If you do not now smoke or chew tobacco, but have in the past, how long has it been since you quit smoking or chewing.

    1. Less than a year ago _____
    2. More than a year ago _____
    3. Not applicable to me _____

18. Do you currently take any medications regularly?

    1. yes ____
    2. no ____

19. If you answered yes to question 18, please list the medications and the reasons for taking them.

20. Have you ever experienced an allergic reaction to a drug?

    1. yes ____
    2. no ____

21. If you answered "YES" to question 20, please list the drug and describe the reaction.

On the following page is a section about your USUAL caffeine consumption. Thinking back over the last year, indicate how often you usually eat or drink the foods or medications listed.

Instructions: First indicate your serving. Second, fill in a bubble for the number of times you usually have the item in that amount. Third, fill in the bubble indicating the time period for the number of times you usually have that item in that amount.

Example: A person drinks 3 mugs of brewed coffee per day.

Under brewed coffee you would fill in the bubbles: mug, 3, and day.
(See first question on next page for this example.)

	YOUR SERVING	NUMBER OF TIMES:	PER:
COFFEE		none 1 2 3 4 5 6 7	day week month year
Brewed	○ cup ○ mug		
Instant	○ cup ○ mug		
MRE Coffee	1 package		
TEA		none 1 2 3 4 5 6 7	day week month year
Brewed	○ cup ○ mug		
Instant	○ cup ○ mug		
Iced Tea	○ 8oz ○ 12oz		
Ration Tea	1 package		
COCOA		none 1 2 3 4 5 6 7	day week month year
Chocolate Milk	○ cup ○ mug		
Cocoa/Hot Chocolate	○ cup ○ mug		
MRE Cocoa Mix	1 package		
CANDY		none 1 2 3 4 5 6 7	day week month year
Milk Chocolate	1 ounce		
Dark Chocolate	1 ounce		
Other Candy_____	_____		
MRE M&M	1 package		
Ration Brownie	1 package		
SOFT DRINKS		none 1 2 3 4 5 6 7	day week month year
Cola-Type	○ 12oz ○ 16oz		
Dr. Pepper	○ 12oz ○ 16oz		
Mr. PIBB	○ 12oz ○ 16oz		
Big Red	○ 12oz ○ 16oz		
Mountain Dew	○ 12oz ○ 16oz		
Mello Yello	○ 12oz ○ 16oz		

Please indicate which of these medications you take regularly (two or more times per week).

- ○ No Doz
- ○ Vivarin
- ○ Aspirin
- ○ Anacin
- ○ Excedrin
- ○ Coryban-D
- ○ Dristan
- ○ Triaminicin
- ○ Soma Compound
- ○ Darvon Compound
- ○ Weight Control Aids
- ○ Other:_____

Other Candy

	0	1	2	3	4	5	6	7	8	9
other										

Please Do Not Write in This Box

	0	1	2	3	4	5	6	7	8	9
servy										

Subject Number

0	1	2	3	4	5	6	7	8	9

4708

PROFILE OF MOOD STATES

LAST NAME: _____ SUBJECT NUMBER: _____ DATE: _____

Below is a list of words that describe feelings people have. Please read each one carefully. Then mark ONE square under the answer to the right which best describes HOW YOU FEEL RIGHT NOW.
Please use a number two pencil to mark the squares.

The numbers refer to these phrases:

NOT AT ALL 0	A LITTLE 1	MODERATELY 2	QUITE A BIT 3	EXTREMELY 4
Friendly	Unworthy	Desperate		
Tense / Angry	Spiteful / Sympathetic	Sluggish / Rebellious		
Worn out / Unhappy	Uneasy / Restless	Helpless / Weary		
Clear-headed / Lively	Unable to concentrate / Fatigued	Bewildered / Alert		
Confused / Sorry for things done	Helpful / Annoyed	Deceived / Furious		
Shaky / Listless	Discouraged / Resentful	Efficient / Trusting		
Peeved / Considerate	Nervous / Lonely	Full of pep / Bad-tempered		
Sad / Active	Miserable / Muddled	Worthless / Forgetful		
On edge / Grouchy	Cheerful / Bitter	Carefree / Terrified		
Blue / Energetic	Exhausted / Anxious	Guilty / Vigorous		
Panicky / Hopeless	Ready to fight / Good natured	Uncertain about things / Bushed		
Relaxed	Gloomy			

MAKE SURE YOU HAVE ANSWERED EVERY ITEM.

Subject Number 0 1 2 3 4 5 6 7 8 9

PLEASE DO NOT WRITE IN THIS BOX

Iteration 0 1 2 3 4 5 6 7 8 9

7715

STANFORD SLEEPINESS SCALE

SUBJECT NUMBER _____

Directions: Please draw a circle around the single rating that best describes how you feel right now.

1. Feeling active and vital; alert; wide awake.
2. Functioning at a high level, but not at a peak; able to concentrate.
3. Relaxed; awake; not at full alertness; responsive.
4. A little foggy; not at peak; let down.
5. Fogginess; beginning to lose interest in remaining awake; slowed down.
6. Sleepiness; prefer to be lying down; fighting sleep; woozy.
7. Almost in reverie; sleep onset soon; lost struggle to remain awake.

POST-TEST QUESTIONNAIRE

SUBJECT NUMBER _____

Directions: Please answer the possible three questions as accurately as possible.

1) Which drug do you think you were given?

_____ Caffeine _____ Placebo

2) If you feel you received caffeine, do you think it:

_____ Helped you

_____ Made you worse

_____ Neither helped nor hurt

_____ Unsure

Please explain why:

3) Did you feel you had any negative side effects from caffeine?

_____ Yes _____ No _____ Unsure

If yes, what were they - circle all that apply:

a. dizziness

b. heart palpitations (extra beats)

c. blurry vision

d. nervousness

e. other - explain

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